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Frontispiece

THE
REMOVAL AND DISPOSAL OF TOWN REFUSE.

BY

WILLIAM H. MAXWELL,

ASSISTANT ENGINEER AND SURVEYOR, LEYTON URBAN DISTRICT COUNCIL.

WITH NUMEROUS ILLUSTRATIONS.

LONDON:
THE SANITARY PUBLISHING COMPANY, LTD.,
5, Fetter Lane, Fleet Street, E.C.
1898.

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JUN 12 1900

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PREFACE.

A GOOD deal has been written from time to time, either in the form of detached "papers," reports, or pamphlets, upon the question of the "Removal and Disposal of the Refuse of Towns," but no attempt has yet been made, so far as I am aware, to deal with the subject from the practical point of view in the compass of a single volume and in a manner in any way approximating to completeness.

The aim of the present work, therefore, has been to treat of all phases of this important question so far as concerns the interests of Sanitary Authorities and their officers, and for that purpose have been included—a *résumé* of the *law* bearing on the subject; a consideration of the *nature* of town refuse; a discussion of the various systems of its *collection*; and, finally, an investigation of the methods of its sanitary and economical *disposal*, or, in some cases, *utilisation.*

To attempt to minimise the importance of the question of the removal and disposal of refuse would be to grossly ignore the very essentials of sanitary science and of a reasonably healthful existence. In fact, to systematically *remove* all refuse, in whatever form it may present itself, and to successfully *dispose* of it when so removed, is the backbone of the whole of the teaching of sanitary science and of the secret of the health of the population.

The increasing urgency of the subject, as will be obvious, will be proportionate to the growth of towns, and particularly is this so as regards the question of "disposal." Special attention, therefore, has been directed to this, more especially in regard to the disposal of refuse by fire, which has now become general in all large towns.

Mere *disposal* or riddance, however, is not by any means the only consideration in dealing with this material. For some years scientific experts, municipal engineers, and Public Authorities have been directing careful attention to the *utilisation* of refuse as fuel for steam production, and substantial progress in this direction has been made of late. Consequently this aspect of the question has been prominently kept in view, and the details of the evaporative value of refuse, and the uses to which the power thus obtained is applied, have been given wherever this information was available.

In many towns, it will be observed, refuse is regarded as a valuable fuel, and successful efforts are being made to utilise its full calorific value. It may be further noticed that in a number of the newer destructor installations the motive power derived is considerable, and is daily employed in operating all sorts of machinery—such, for example, as for the pumping of town sewage, for grinding mortar, generating electricity for light and motive power, supplying steam to municipal workshops, stables, and such like.

It is thus demonstrated where steam power is required that the burning of a low-class fuel such as house refuse in suitably constructed furnaces provides a profitable outlet for an apparently useless and most unpromising material.

At the moment of the birth and first dissemination of the idea of lighting a town by electricity solely or mainly by means of the heat derivable from the burning of its house and other refuse, the economical importance of a combined undertaking of this character very naturally presented a somewhat fascinating stimulus to Public Authorities, and possibly has had much to do with the recent development both of the adoption of the principle of dealing with refuse by fire and also of lighting towns by electricity. The views of many, however, were probably at first somewhat too sanguine as to the capabilities of such a combination, but from experience since gained it may be taken as demonstrated that a destructor installation properly designed is capable of affording a useful adjunct in the supply of power to an electric or other power-using undertaking. Also, when a system of thermal storage can be introduced in a reliable and workable manner the degree of success will be materially enhanced.

In treating of the characteristic points and capabilities of the various designs of destructor furnaces, the facts and *working results* of each have been stated without partiality towards any particular *type* of furnace; and, in regard to the question as to which furnace is the best for adoption in any new installation, to the practical mind the facts so stated will doubtless speak for themselves.

In connection with the preparation of the latter portion of the book dealing with "Refuse Disposal and Destructor Installations at Various Towns," I am indebted in nearly every case to the Borough Engineers and Surveyors at the towns described, both at home and abroad, for the information, plans, and details they have so kindly and liberally furnished me with, without which valued assistance this section could not have been written.

The greatest care has been taken so far as possible to ensure accuracy in the details of the installations mentioned, which, it is hoped, will be found sufficiently full for all practical purposes, in spite of a constant effort to condense into a form convenient for reference.

In conclusion, in issuing this work I trust that it may be found to be of service not only to Municipal Engineers and Surveyors, but also to members of Sanitary Authorities, in carrying out their investigations into a subject which must ever constitute one of the most arduous and important duties which a Local Authority has to perform.

WILLIAM H. MAXWELL.

Town Hall, Leyton,
1898.

THE REMOVAL AND DISPOSAL OF THE REFUSE OF TOWNS.

CHAPTER I.

GENERAL REMARKS.

THE removal and disposal of the various forms of refuse usually created by the large populations of cities and towns includes:—

1. *The Scavenging and Cleansing of Streets*, with the collection and removal of street sweepings and gully deposits.
2. *The Collection of House and Trade Refuse*, and the ultimate disposal of same by cremation in refuse destructors or otherwise.
3. *The Removal and Disposal of Excreta* from the pail, privy, cesspool, or midden, or of "sewage" (as it is called when largely diluted with waste water), by means of a system of sewers, thus involving the whole question of the construction of "sewerage" and sewage disposal works.

In fact, works connected with the "removal of refuse" in some form or other is now becoming one of the most onerous and important duties devolving upon the Town Surveyor.

The subjects of sewerage and sewage disposal, however, are of such magnitude that, although being truly works for the "Removal and Disposal of Refuse," they are not usually understood to be included under this general heading—the term "refuse" being more popularly applied to what is known as *House*, *Trade*, and *Street* refuse only, and to the consideration of which the following pages are intended to be devoted.

In order to ensure and assist the efficient execution of this work, certain important legal powers and obligations have been given to Local Authorities and occupiers respectively. Those applicable to the provinces (*England*, but not Scotland or Ireland[1]) are to be found in the Public Health Act, 1875, under the heading of "Scavenging and Cleansing," Sections 42 to 45, whilst similar provisions (but with certain improvements) for the Metropolis are contained in the Public Health (London) Act, 1891, under the heading of "Removal of Refuse," Sections 29 to 36. It will be necessary before proceeding with the consideration of the practical side of this subject to refer to the above clauses, under which the work is executed, in detail.

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[1] See Section 2, Public Health Act, 1875.

PUBLIC HEALTH ACT, 1875.

The Public Health Act, 1875, provides as follows:—

Cleansing of Streets and Removal of Refuse. — Every Local Authority *may*, and when required by order of the Local Government Board *shall*, themselves undertake or contract for—

"The removal of *house refuse* from premises.

"The *cleansing of earth closets*, privies, ashpits, and cesspools, either for the whole or any part of their district. Moreover, every Urban Authority and any Rural Authority invested by the Local Government Board with the requisite powers may, and when required by order of the said Board shall, themselves undertake or contract for the proper *cleansing of streets*, and may also themselves undertake or contract for the proper *watering of streets* for the whole or any part of their district.

"All matters collected by the Local Authority or contractor in pursuance of this section may be *sold or otherwise disposed of*, and any profits thus made by an *Urban* Authority shall be carried to the account of the fund or rate applicable by them for the general purposes of this Act; and any profits thus made by a *Rural* Authority in respect of any contributory place shall be carried to the account of the fund or rate out of which expenses incurred under this section by that Authority in such contributory place are defrayed.

"If any person *removes or obstructs* the Local Authority or contractor in removing any matters by this section, authorised to be removed by the Local Authority, he shall for each offence be liable to a penalty not exceeding *five pounds*, provided that the occupier of a house within the district shall not be liable to such penalty in respect of any such matters which are produced on his own premises, and are intended to be removed for sale or for his own use, and are in the meantime kept so as *not to be a nuisance*." (38 and 39 Vic., Chap. 55, s. 42).

It will be noticed that the provisions as to "streets" in the above section apply to both "public" and "private" streets; and it may also be mentioned in this connection that Urban Authorities are authorised, by Section 148 Public Health Act, 1875, to undertake, by agreement, the cleansing and watering of "*private*" streets, it being, of course, as important from a sanitary point of view that these should be cleansed and watered as well as "*public*" streets.

Penalty on Neglect of Local Authority to remove Refuse, &c.—"If a Local Authority, who have themselves undertaken or contracted for the removal of house refuse from premises, or the cleansing of earth closets, privies, ashpits, and cesspools, fail, without reasonable excuse, after notice in writing from the occupier of any house within their district, requiring them to remove any house refuse, or to cleanse any earth closet, privy, ashpit, or cesspool belonging to such house, or used by the occupiers thereof, to cause the same to be removed or cleansed, as the case may be, within seven days, the Local Authority shall be liable to pay to the occupier of such house a penalty not exceeding *five shillings* for every day during which such default continues after the expiration of the said period." (38 and 39 Vic., Chap. 55, s. 43).

Glen's "Law Relating to Public Health and Local Government,"[1] eleventh edition, vol. I., under this section cites several cases, showing what substances may *not* be considered "refuse" under this Act, but no definition as to what *is* refuse is suggested. The terms "*house*," "*trade*," and "*street refuse*," are, however, clearly defined in Sect. 141 of the Public Health (London) Act, 1891, and which interpretation will presently be given when special reference is made to that Act. The same authority states that "the definition of '*house*' in Sec. 4, is not to be imported into Secs. 42 and 43, so as to extend the ordinary meaning of 'house refuse' to the refuse from factories, &c."

Power of Local Authority to make By-laws Imposing Duty of Cleansing, &c., on Occupier.—"Where the Local Authority do not themselves undertake or contract for—

"The cleansing of footways and pavements adjoining any premises;

"The removal of house refuse from any premises;[2]

"The cleansing of earth closets, privies, ashpits, and cesspools belonging to any premises."

They may make *by-laws* imposing the duty of such cleansing or removal, at such intervals as they think fit, on the occupier of any such premises.

"An *Urban* Authority may also make by-laws for the prevention of nuisances arising from snow, filth, dust, ashes, and rubbish, and for the prevention of the keeping of animals on any premises so as to be injurious to health." (38 and 39 Vic., Chap. 55, s. 44.)

The Memorandum of the Local Government Board to the Model By-laws with respect to the cleansing of foot ways and pavements, &c., states that by-laws under this section "must be limited to imposing upon the occupier the duty of cleansing or removal, at such intervals as the Sanitary Authority may think fit. The mode of cleansing or removal, and the precautions to be observed in connection with the process are not matters within the range of such by-laws."

The above section (44) is extended by Section 26 of the Public

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[1] An invaluable standard legal work, published by Messrs. Knight and Co.

[2] "*House*," includes schools, also factories and other buildings in which *more than twenty* persons are employed *at one time*. The words italicized are repealed by 41 Vict., c. 16, s. 107, and sched. vi.

Health Acts (Amendment) Act, 1890, whereby an Urban Authority, having adopted that Act, may make by-laws for the proper and cleanly removal of offensive matter or liquid, at suitable times prescribed by them, in properly constructed and covered vessels or carts, and also for compelling the cleansing of places soiled by any of the matter or liquid which may have been spilt in such removal. Also, "where a Local Authority themselves undertake or contract for the removal of *house refuse* they may make by-laws imposing on the occupier of any premises duties in connection with such removal, so as to facilitate the work which the Local Authority undertake or contract for."

The same Act further provides in Section 27 as follows: — "Where any court, or where any passage leading to the back of several buildings *in separate occupations*, and not being a highway repairable by the inhabitants at large, is not regularly and effectually swept and kept clean and free from rubbish or other accumulation to the satisfaction of the Urban Authority, the Urban Authority may, if they think fit, cause to be swept and cleaned such court or passage. The expenses thereby incurred shall be apportioned between the occupiers of the buildings situated in the court or to the back of which the passage leads, in such shares as may be determined by the surveyor of the Urban Authority, or, in case of dispute, by a court of summary jurisdiction, and in default of payment, any share so apportioned may be recovered summarily from the occupier on whom it is apportioned."

This section is a very needful one, and requires to be universally taken advantage of, as these passages affording back entrances to separate premises very usually become, sooner or later, nothing more or less than public depôts for an indescribable mass of heterogeneous rubbish, including old buckets, kettles, fish tins, crockery, large quantities of garden refuse, &c., thrown out mainly by the abutting occupiers. Oftentimes to walk through such a place in the daytime would be at the risk of one's limbs, and in the night probably fatal.

Power to provide Receptacles for Deposit of Rubbish.—The next section of the 1875 Public Health Act provides that "any Urban Authority may, if they see fit, provide in proper and convenient situations receptacles for the temporary deposit and collection of dust, ashes, and rubbish; they may also provide fit buildings and places for the deposit of any matters collected by them in pursuance of this part of this Act." (38 and 39 Vict., Chap. 55, s. 45).

PUBLIC HEALTH (LONDON) ACT, 1891.

The subject of the "Removal of Refuse" has received a large share of attention in the Public Health (London) Act, 1891, and is based upon what is universally acknowledged as the best sanitation of the day. The interpretation clause[1] of that Act gives the following important definitions:—

"*House Refuse*" means ashes, cinders, breeze, rubbish, night-soil, and filth, but does not include trade refuse.

"*Trade Refuse*" means the refuse of any trade, manufacture, or business, or of any building materials.

"*Street Refuse*" means dust, dirt, rubbish, mud, road scrapings, ice, snow, and filth.

"*Ashpit*" means any ashpit, dust-bin, ash-tub, or other receptacle for the deposit of ashes or refuse matter.

The following clauses of the Act are those bearing upon the subject under consideration:—

Duty of Sanitary Authority to Cleanse Street and Footways.—"It shall be the duty of every Sanitary Authority to keep the streets of their district, which are repairable by the inhabitants at large, including the footways, properly swept and cleansed, so far as is reasonably practicable, and to collect and remove from the said streets, so far as is reasonably practicable, all street refuse.

"If any such street in the district of any Sanitary Authority, including the footway, is not properly swept and cleansed, or the street refuse is not collected and removed from any such street, so far as is reasonably practicable, as required by this section, the Sanitary Authority shall be liable to a fine not exceeding *twenty pounds.*

"So much of any Act as requires the *occupier or owner* of any premises in London to cause the footways and water-courses adjoining the premises to be swept and cleansed is hereby repeated." (54 and 55 Vict., Chap. 76, s. 29.)

Removal of House Refuse.—"It shall be the duty of every Sanitary Authority—(*a*) to secure the due removal at proper periods of *house refuse* from premises, and the due cleansing out and emptying at proper periods of ashpits, and of earth closets, privies, and cesspools (if any), in their district, and the giving of sufficient notice of the times appointed for such removal, cleansing out, and emptying; and (*b*) where the house refuse is not removed from any premises in the district at the ordinary period, or any ashpit, earth closet, privy, or cesspool in or under any building in the district, is not cleansed out or emptied at the ordinary period, and the occupier of the premises serves on the Authority a written notice requiring the removal of such refuse, or the cleansing out and emptying of the ashpit, earth closet, privy, or cesspool, as the case may be, to comply with such notice within *forty eight* hours after that service, exclusive of Sundays and public holidays.

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[1] 54 and 55 Vic., Ch. 76, s. 141.

"If a Sanitary Authority fail without reasonable cause to comply with this section, they shall be liable to a fine not exceeding *twenty pounds*.

"If any person in the employ of the Sanitary Authority, or of any contractor with the Sanitary Authority, demands from an occupier or his servant any fee or gratuity for removing any house refuse from any premises, he shall be liable to a fine not exceeding *twenty shillings*." (54 and 55 Vict., Chap. 66, s. 30.)

Sanitary Authority to Appoint Scavengers. — "Every Sanitary Authority shall employ a sufficient number of scavengers, or contract with any scavengers, whether a company or individuals, for the execution of the duties of the Sanitary Authority under this Act with respect to the sweeping and cleansing of the several streets within their district, and the collection and removal of *street refuse* and *house refuse*, and the cleansing out and emptying of ashpits, earth closets, privies, and cesspools." (54 and 55 Vict., Chap. 76, s. 31.)

Disposal of Refuse.—"All *street refuse* and *house refuse* collected by or on behalf of a Sanitary Authority shall be the property of that Authority, and the Authority shall have full power to sell and dispose of the same for the purposes of this Act as they may think proper, and the person purchasing the same shall have full power to take, carry away, and dispose of the same for his own use, and the money arising from the sale thereof shall be applied towards defraying the expenses of the execution of this Act." (54 and 55 Vict., Chap. 76, s. 32.)

Owners, &c., to Pay for Removal of Trade Refuse.—"If the Sanitary Authority are required by the owner or occupier of any premises to remove any *trade refuse*, that Authority shall do so, and the owner or occupier shall pay to that Authority a reasonable sum for such removal, and such sum, in case of dispute, shall be settled by the order of a petty sessional court.

"If any dispute or difference of opinion arises between the owner or occupier and the Sanitary Authority as to what is to be considered as *trade* refuse, a petty sessional court, on complaint made by either party, may by order determine whether the subject matter of dispute is or is not trade refuse, and the decision of that court shall be final." (54 and 55 Vict., Chap. 76, s. 33.)

Provision on Neglect of Scavengers to Remove Dust.—"If the Sanitary Authority, or any persons employed by them, neglect for the space of seven days to remove all such *house refuse* as they are required by or in pursuance of this Act to remove, then an occupier of premises (after twenty-four hours' notice given by him to the

Sanitary Authority requiring them to remove the same) may without prejudice to any other proceeding under this Act give away or sell his house refuse; and any person who in pursuance of such gift or sale removes the said house refuse shall not be liable to any fine for so doing.

"Save as aforesaid, if any person other than the Sanitary Authority or their contractors or servants receives, carries away, or collects any house refuse or street refuse from any premises or street, such person shall be liable to a fine not exceeding five pounds." (54 and 55 Vict. Chap. 76, s. 34.)

Removal of Filth on Requisition of Sanitary Inspector.—Where it appears to a *Sanitary Inspector* that any accumulation of any obnoxious matter, whether manure, dung, soil, filth, or other matter, ought to be removed, and it is not the duty of the Sanitary Authority to remove the same, he shall serve notice on the owner thereof, or on the occupier of the premises on which it exists, requiring him to remove the same, and if the notice is not complied with within forty-eight hours from the service thereof, exclusive of Sundays and public holidays, the matter referred to shall be the property of the Sanitary Authority, and be removed and disposed of by them, and the proceeds (if any) of such disposal shall be applied in payment of the expenses incurred with reference to the matter removed, and the surplus (if any) shall be paid on demand to the former owner of the matter.

"The expenses of such removal and disposal, so far as not covered by such proceeds, may be recovered by the Sanitary Authority in a summary manner from the former owner of the matter removed, or from the occupier, or, where there is no occupier, the owner of the premises." (54 and 55 Vict., Chap. 76, s. 35.)

Removal of Refuse from Stables, Cowhouses, &c.—"The Sanitary Authority, if they think fit, may employ a sufficient number of scavengers, or contract with any scavengers whether a company or individuals, for collecting and removing the *manure and other refuse matter* from any *stables and cowhouses* within their district, the occupiers of which signify their consent in writing to such removal; provided that—

"(*a*) Such consent shall not be withdrawn or revoked without one month's previous notice to the Sanitary Authority, and

"(*b*) No person shall be hereby relieved from any fine to which he may be subject for placing dung or manure upon any footways or carriageways, or for having any accumulation or deposit of manure or other refuse matter so as to be a nuisance or injurious or dangerous to health.

"Notice may be given by a Sanitary Authority (by public announcement in the district or otherwise) requiring the periodical removal of manure or other refuse matter from stables, cowhouses, or other premises; and, where any such notice has been given, if any person to whom the manure or other refuse matter belongs fails to comply with the notice, he shall be liable without further notice to a fine not exceeding twenty shillings for each day during which such non-compliance continues." (54 and 55 Vict., Chap. 76, s. 36).

MODEL BY-LAWS.

By-laws.—The Model By-laws issued by the Local Government Board under Section 44 of the Public Health Act, 1875, provide for—

The Cleansing of Footways and pavements adjoining any premises by the occupier at regular specified intervals.[1]

The Removal of House Refuse from any premises by the occupier at regular intervals suited to the locality.

The Cleansing of Earth Closets with both movable and fixed receptacles, privies (receptacles either movable or fixed), ashpits (including ashpits used in connection with privies), and cesspools belonging to any premises. The penalty usually inserted by Sanitary Authorities in these by-laws for non-compliance is £5.

Of course, where Local Authorities themselves undertake or contract for the above matters the necessity for *these* by-laws ceases; but others will be required to be made by the Sanitary Authority imposing on the occupier of any premises, *duties* in connection with the removal of house refuse, so as to facilitate the work of collection. For example, in an urban district where the "pail system" of collection has been adopted, the following by-law was made in order to assist the Authority in the work of collection:—

"The occupier of any premises on which any house refuse may from time to time accumulate, shall on such days, and at such hour of the day as the Sanitary Authority shall fix and shall notify by public announcement in the district, deposit on the curbstone, or on the outer edge of the footpath, immediately in front of such premises, or in a conveniently accessible position on the premises as the Sanitary Authority may prescribe by written notice served upon the occupier, a movable receptacle, in which shall be placed for the purpose of removal by or on behalf of the Sanitary Authority, the house refuse which has accumulated on such premises since the preceding collection by or on behalf of the Sanitary Authority."

BY-LAWS OF LONDON COUNTY COUNCIL.

The by-laws made by the London County Council, under Sec. 39

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[1] In *London* this duty lies entirely with the Sanitary Authority (see 54 and 55 Vict., Chap. 76, Sec. 29, *ante.*)

(1) of the Public Health (London) Act, 1891, so far as they relate to "*house refuse,*" include the following:—

"When any person shall provide an *ashpit* in connection with a building, he shall cause the same to consist of one or more *movable* receptacles sufficient to contain the 'house refuse' which may accumulate during any period not exceeding *one week.* Each of such receptacles shall be constructed of *metal,* and shall be provided with one or more suitable *handles* and *cover.* The *capacity* of each of such receptacles shall not exceed *two cubic feet.*

"Provided that the requirement as to the size of each of such receptacles shall not apply to any person who shall construct such receptacle or receptacles in connection with any premises to which there is attached as part of the conditions of tenancy the right to dispose of house refuse in an ashpit used in common by the occupiers of several tenancies, but in no case shall such ashpit be of greater capacity than is required to enable it to contain the refuse which may accumulate during any period not exceeding one week.

"The occupier of any premises who shall use any *ashpit* shall, if such ashpit consist of a *movable receptacle,* cause such receptacle to be kept in a covered place, or to be properly covered, so that it shall not be exposed to rainfall, and if such ashpit consist of a *fixed receptacle,* he shall cause the same to be kept properly covered.

"Where the Sanitary Authority have arranged for the *daily removal of house refuse* in their district, or in any part thereof, the owner of any premises in such district or part thereof shall provide an ashpit which shall consist of one or more movable receptacles, sufficient to contain the house refuse which may accumulate during any period not exceeding three days, which the Sanitary Authority may determine, and of which the Sanitary Authority shall give notice by public announcement in their district. Each of such receptacles shall be constructed of *metal,* and provided with one or more suitable *handles* and *cover.* The *capacity* of each of such receptacles shall not exceed *two cubic feet.*

"Provided always that this by-law shall not apply to the owner of any premises until the expiration of three months after the Sanitary Authority have publicly notified their intention to adopt a system of daily collection of house refuse in that part of their district which comprises such premises.

"Where any receptacle shall have been provided as an ashpit for any premises in pursuance of any by-law in that behalf, no person shall deposit the *house refuse* which may accumulate on such premises in any ashpit that does not comply with the requirements of these by-laws."

Cesspools, where constructed in connection with buildings, are to be at least 100ft. from those used for human habitation, or from any well, spring, or stream of water.

They must be constructed to afford ready means of access for cleansing, &c., and so that their contents may be removed without passing through buildings used for human habitation. The cesspool must not connect in any way to a sewer; and is to be formed of good brickwork bedded and grouted in cement and rendered inside, and to have a backing of at least 9in. of well-puddled clay around and beneath the brickwork, and thus made perfectly water-tight. Also, it is to be arched or otherwise properly covered over and well ventilated.

Receptacles for Dung.—These must not be constructed so that one side is formed by the wall of a dwelling-house, or in a situation where they are likely to give rise to a nuisance. Owners of existing receptacles are required, within six months from the commencement of the operation of the by-laws, and all makers of new receptacles, to form them of a capacity not exceeding two cubic yards, and so that their floors and bottoms shall not be below the adjoining ground. Also, they shall be easily accessible for cleansing, shall be water-tight, rain-proof, and well ventilated.

If, however, the manure is removed every forty-eight hours, the size is not limited to two cubic yards, as above. And where only the dung of horses, asses, or mules with stable litter is produced, and where the removal is effected every forty-eight hours, a metal cage may be provided in lieu of the above receptacle, the ground beneath same being paved to prevent soakage.

Maintenance of Sanitary Receptacles.—"The owner of any premises shall maintain in proper condition and repair every water-closet, earth-closet, privy, ashpit, cesspool, and receptacle for dung, and the proper accessories thereof belonging to such premises."

Penalty.—The penalty for offence against the foregoing by-laws is £5, and 40s. per day in the case of a continuing offence.

THE SCAVENGING AND CLEANSING OF STREETS.

The word "Scavenger" is of Saxon origin[1], and is derived from a root signifying "to shave," or "sweep." It means a "petty magistrate whose province it is to keep the streets clean," or, more commonly, "the labourer employed in removing filth" from the streets. In early times when the practice of throwing refuse into the streets was very much more general than at present, the business of "scavenging" was practically confined to *street cleansing*, the "*dust-bin*," as we understand it, being then practically unknown.

As an example of the filthy state of town streets in olden times reference may be made to the streets of Dublin, in respect to which, by way of a remedial measure, a writ was issued in 1489 to "Mayor and Bailiffs of Dublin, from Gerald, Earl of Kildare, Deputy to Jaspar, Duke of Bedford, Lieutenant of Ireland for Henry VII. The King has been informed that *dung heaps*, *swine*, *hogsties*, *and other nuisances in the streets*, *lanes*, and suburbs of Dublin, infect the air and produce mortality fevers and pestilence throughout that city. Many citizens and sojourners have thus died in Dublin. *The fear of pestilence prevents the coming thither of lords*, *ecclesiastics*, *and lawyers*. Great detriments thence arise to his Majesty, as well as dangers to his subjects, and impediments to business. The King commands the Mayor and Bailiffs to cause forthwith the removal of all swine, *and to have the streets and lanes freed from ordure*, *so as to prevent loss of life from pestilential exhalations*."

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[1] Dr. Johnson.

Another decree required that "every householder must cleanse the portion of the street before his own door, under penalty of 12d."

The importance of "scavenging," from a sanitary point of view, being carried out systematically and efficiently throughout any municipal area cannot be over-estimated. Sir Robert Rawlinson, at a meeting of Engineers at Stratford-upon-Avon (1885), urged it as the most essential feature towards a healthy district in the following terms:—"*The foundation of all sanitary science is scavenging;* and if I were asked what is the most important feature in sanitary science, I would repeat again *scavenging*. Your sewers, your drains, and water supply are all secondary considerations if scavenging is neglected. . . . . And I say, as a last word to the people of Stratford-on-Avon, mature your scavenging arrangements and make them perfect."[1]

The necessity for urgent removal, and a speedy and inoffensive disposal of both house and street refuse, is recognised by the Public Health (London) Act, 1891, which, by Section 22, constitutes it an "*offensive trade*," and provides for the abatement of nuisances created by Sanitary Authorities in dealing with refuse, as follows:—

"The removal of *house refuse* and *street refuse* by a Sanitary Authority when collected or deposited by that Authority shall be deemed to be a business carried on by that Authority within the meaning of the last preceding section (which provides for the abatement of nuisances arising from offensive trades), and a complaint or proceedings under that section in relation to any such business may be made or taken by the County Council in like manner as if the Council were a Sanitary Authority.

"Any *premises used* by a Sanitary Authority *for the treatment or disposal of any street refuse or house refuse*, as distinct from the removal thereof, which are a nuisance or injurious or dangerous to health, shall be a nuisance liable to be dealt with summarily under this Act, and for the purpose of the application thereto of the provisions of this Act relating to such nuisances the County Council shall be deemed to be a Sanitary Authority." (54 and 55 Vic., cap. 76, Sec. 22.)

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[1] "Proceedings" of the Association of Municipal and County Engineers, vol. xii.

"*Street refuse*" comprises the whole of the refuse, both wet and dry, obtained from the surfaces of the streets, and includes "dust, dirt, rubbish, mud, road scrapings, ice, snow, and filth," also deposits from street gullies.

The facilities, or otherwise, for the cleansing of streets, necessarily depend very largely indeed upon the formation, nature, and degree of repair of the street surfaces. The harder and more impervious to moisture the street surface material, the better will it admit of efficient cleansing; and therefore the more sanitary pavement will it be.

From a hygienic point of view, Major Isaacs has laid down[1] the following essential points for a good pavement:—

(1) It must effectually prevent the rising of exhalations from the ground on which it is superimposed.

(2) It must be non-absorbent of moisture, so as to give off the least possible amount of offensive effluvia from its own surface.

(3) It must be well drained, both longitudinally and transversely, so that water cannot remain on its surface.

(4) It must be easily cleansed.

(5) It must be as free from dust and mud as possible.

(6) It must be as noiseless as possible.

The surfaces of streets are formed either of macadam or gravel, wood, granite, or asphalt, which materials vary considerably as regards the facilities respectively offered for scavenging and cleansing purposes.

Macadam and gravel surfaces are undoubtedly the most undesirable for scavenging purposes, and are usually abolished as soon as the surrounding areas become fully built upon. In suburban districts this class of roadway almost universally prevails owing to its low initial cost, although tar macadam may be, and has been, in many instances, substituted with considerable advantage—being impervious to moisture, and much less costly to scavenge, and water.

It will be noticed that macadam and gravel carriageways fail entirely to comply with the essentials for a hygienic pavement as laid down by Mr. Isaacs, excepting to some degree, as regards noiselessness. Such surfaces are of an exceptionally absorbent nature, and are therefore apt to give off offensive effluvia from malodorous deposits frequently dropped upon them. Excessive quantities of mud and dust are produced in wet and dry weathers respectively, to the serious discomfort and annoyance of both pedestrians and occupiers of the adjoining properties. The dust, too, contains a large percentage of organic matter which is set in motion by the wind, and is consequently inhaled by those frequenting the streets. Macadam surfaces also soon get out of repair, and thus considerably increase the difficulty of scavenging.

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[1] "The Construction of Roads and Streets from a Sanitary Point of View." Sanitary Institute "Journal," vol. xv., part 2.

Wood pavements have been very extensively adopted, and are popularly much appreciated, chiefly on account of their noiselessness and ease of traction. A serious objection, however, is their absorptive nature, allowing foul matters to penetrate into the fibre of the wood, there decomposing, and in warm weather giving off miasmatic exhalations into the atmosphere of the streets. This evil is naturally at its worst when the pavement is allowed to get into a bad state of repair, and cannot, therefore, be properly scavenged. "The Board of Health Committee of Washington, in a report upon this subject, remarked that probably four-fifths of the newly-paved streets of their city were paved with wood varying in kind, some having been treated with antiseptics before being laid, and that within three years from the time they were laid every one of them gave more or less evidence of very rapid decomposition, and some of them had decayed so rapidly as to give rise to a mass of dangerous putrefaction; that, moreover, the broken surface of the pavement above mentioned had allowed the lodgment of an immense quantity of animal and vegetable filth, impossible even to calculate, between and under the blocks of wood, not only greatly increasing the putrefying mass, but adding to the rapidity of its decomposition; and that from the said decomposition gases arose, fungi and infusoria developed, which, entering the air breathed, were poisonous, engendering zymotic diseases, such as typhoid, malarial, and intermittent fever, dysentery, diphtheria, &c."[1]

Considerable improvements in the laying down of wood pavements have been effected of late years, minimising, to a great extent, the evils above cited. The introduction of the *hard woods*, such as Karri, Jarrah, blue gum, black butt, spotted gum, &c., and the use of *close joints* filled with bitumen, have done much towards rendering the surface impervious as compared with the former *soft wood* pavement with wide joints of cement or even lime.

Wood pavements also afford a fairly good foothold for horses, and admit of being thoroughly cleansed by the liberal application of water.

Granite surfaces, if maintained in *good order*, are well adapted for cleansing and scavenging, but have, in many instances, been replaced with wood on account of the great noise caused by the traffic. They form, however, a good sanitary pavement, and for very busy thoroughfares with heavy traffic cannot be surpassed.

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[1] "Journal" of Sanitary Institute, vol. xv., part 2, page 148.

Asphalt.—As a sanitary pavement, asphalt undoubtedly takes the first place. It is jointless, can be very easily scavenged and thoroughly washed with a hose. It is also impervious to moisture and to exhalations from the surface upon which it is placed. When kept well cleansed it is not slippery, but it is liable to become so under certain conditions of weather, and for which reason should not be laid upon a gradient steeper than 1 in 60.

The following comparative table[1] shows the amount of mud obtained from the four classes of surfaces mentioned above, and emphasises the importance of the direct bearing of the nature of the surface upon the cost of scavenging:—

Material.	Loads of mud per area. Superficial yards.	Traffic per annum per yard of width. Tons.
Macadam	344	25,000
Granite setts	500	50,000
Wood	1666	25,000
Asphalt	4000	500,000

As a result of special observations, it has been found that, "For four loads of mud or slop removed from a macadam surface, one load is removed from a granite pavement, and one-third of a load from a wood pavement."

The next table from figures also prepared by Mr. Ellice Clark shows the comparative cost of scavenging for the same descriptions of roadway:—

	Scavenging per square yard per annum. d.
Macadam	12·0
Granite	2·5
Wood	2·7
Asphalt	·4

Composition of Street Refuse.—"The dust of the streets in dry, and the mud in wet weather, consists essentially of the *débris* of the stone, metal, or paving, abraded iron, and pulverised horse-dung, in varying proportions. The moisture ranges between 35 per cent. in the driest to 90 per cent. in the wettest weather, ordinary mud yielding about 50 per cent. of water when desiccated. The dry solids, then, average 55 to 60 per cent. of horse-dung, 30 to 35 powdered stone, and 10 to 15 per cent. of abraded iron."[2]

Dr. Letheby's analysis, made in 1867, of mud from London stone-paved streets, of horse-droppings and farmyard manure, dried at a temperature of from 266 deg. to 300 deg. Fah., is useful for comparison, and is as follows:—

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[1] Prepared by Mr. Ellice Clark, *vide* "Proceedings" of the Institution of Civil Engineers, vol. lx

[2] "The Health Officer's Pocket Book," by E. F. Willoughby, M.D. (Lond.); D.P.H. Lond. and Camb.)

Constituents.	Fresh horse-drop'ings	Farm-yard dung.	Mud from stone-paved streets		
			Maximum organic (dry weather).	Minimum organic (wet weather).	Average
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent
Organic ...	82·7	69·9	58·2	20·5	47·2
Mineral ...	17·3	30·1	41·8	79·5	52·8
—	100·0	100·0	100·0	100·0	100·0

It is shown, by the high proportion of mineral matter, that the abrasion of stone and iron is greatest in wet weather. The muds were estimated by Dr. Letheby to consist of the following proportions:—

Horse-dung	57 per cent.
Abraded stone	30 ,,
Abraded iron	13 ,,
	100

The proportion of organic matter in the dried mud of wood pavements amounted approximately to 60 per cent.

What is known as "*slop*" consists very largely of fine grit, and is usually swept by the scavengers to the side channels to await removal in "*slop carts.*" If allowed to lie too long, a large proportion will find its way by gravitation or become washed forward by subsequent showers into the street gullies, sewers, or storm-water culverts, upon which it has a most injurious effect, and can be removed only at considerable trouble and expense. This material "accumulates inside the sewers (especially when the gradients are low . . . .), and, becoming impregnated with the fœcal matter, forms a clammy mass at the bottom of the sewers, which in summer is of considerable thickness, and, from its weight, is never completely washed away, even in winter."[1]

For the health and comfort of the inhabitants of a town the streets cannot be too well scavenged, and the total mud produced and removed decreases by frequent sweeping; and, although the cost may be a little more, the roads will be maintained in a much better state of preservation and the wear and tear considerably reduced. Dust is injurious, not only to tradesmen's goods, but also to the lungs and eye-sight of those using the streets.

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[1] Report by Lieutenant-Colonel C. B. Ewart, R.E., to the Under-Secretary of State, Home Department, on the "Proper Principle of Drainage," which should be adopted in the towns of Oxford, Eton, Windsor, and Abingdon, 1868.

Upon the introduction by Sir Joseph Whitworth of his street-scraping machine in Manchester, it was shown, from calculations as to the relative advantages of machinery and hand-labour, that, in cleansing macadam roadways by machine thrice weekly, the mud produced on the surface was only one-fifth of that created when hand-swept twice in three weeks, and only one-thirteenth of that produced when swept by manual labour once a week.[1]

Methods of Cleansing.—The chief considerations to be borne in mind in organising the necessary work for properly scavenging a municipal area, are well summarised by Mr. H. P. Boulnois,[2] M. Inst. C.E., as follows :—

(1) The *best methods* for sweeping and cleansing streets.

(2) If *machinery* effects such work better and more economically than *hand labour.*

(3) The extra work involved by the *bad construction of streets*, or the ill-chosen materials of which they are formed.

(4) Whether *private streets*, *courts*, and *alleys*, "not repairable by the inhabitants at large," should be swept and cleansed by the Local Authority.

(5) The *ultimate disposal* of excessive accumulations of mud.

(6) The removal and disposal of *snow.*

Courts and Alleys.—The cleansing of these should, on the grounds of *sanitation*, be undertaken by the Public Authority; but the duty is attended with considerable difficulty, owing to the very unsatisfactory state of the surfaces. Many of such courts are not even paved, and others only very badly so with old flags having uneven and wide joints, or with pebbles, thus giving rise to large pools and hollows, filled with stagnant water and decomposing filth, thrown out by the adjoining occupiers; which, especially in summer weather, fills the surrounding atmosphere with pestilential exhalations.

Before deciding upon the cleansing of such courts, an Urban Authority should require them to be properly paved with *asphalt* to facilitate cleansing, and so that they may be liberally flushed with water as frequently as thought necessary. To compel the owners of abutting properties to execute the work of paving these surfaces the Authority would require to proceed under the 150th Section of the Public Health Act, 1875; or, better, under the Private Street Works Act, 1892.

In organising a system of scavenging for a district, in order to ensure success, some *regular routine method* must be determined upon and systematically adhered to, daily, irrespective of weather or other excuse. The area to be scavenged should be divided into conveniently workable sub-divisions, each having allotted to it a sufficient force or gang of men under the direction of a capable foreman or inspector. The business of scavenging is commenced upon the main streets and so continued throughout the entire area.

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[1] Difference of circumstances due to a three-years' interval between the two latter observations may account for the increased mud produced by hand-scraping once weekly over that produced by scraping once in ten days.

[2] "Municipal and Sanitary Engineers' Handbook."

After the traffic has subsided, machine sweeping with horse brooms may be commenced, generally about midnight. Shortly after this, the hand sweepers commence—their duty being to sweep the ridges left on each side of the road by the machines, into heaps, so that they may be taken up by the carts following at five or six o'clock in the morning. The frequency of sweeping and scavenging the streets will necessarily depend upon their respective importance. Main business thoroughfares in towns are swept daily, and secondary streets thrice or twice a week as may be found necessary.

The street slop is swept to the channels, and gully deposits and the dry sweepings are placed in heaps at the sides of the streets by the sweeping gangs; these are followed by scavenging carts for the removal of the refuse, thus leaving the streets and channels quite clean and tidy. Disinfecting powder is frequently sprinkled in and around the street gullies after being cleared, and it is advisable also, especially in dry weather, to recharge them from a water cart immediately after cleaning to ensure a proper depth of water seal.

"The old form of gulley in London consists of simply a straight brick shoot into the sewer, which forms a ventilator for sewer gas delivering directly on to the footpath, poisoning the air for passers-by. This shoot in itself is also nothing more nor less than a generating 'trunk' for foul gases, owing to the filth that necessarily accumulates on the brickwork between the gully grating and the sewer.

"A form of gully very much adopted in London consists of two chambers, one of which acts as a catch pit for sludge, and is capable of holding about a cubic yard of detritus. This gully or catch pit is very liable to be neglected, and only cleaned out when the gully is blocked, thus allowing the accumulated detritus to remain for weeks or months, giving off harmful gases."[1]

A good *street gully* should possess the following points:—

(1) It should be of simple construction, strong, and of a *circular* form—possessing no angles difficult of access for cleansing.

(2) It should have a *deep* water seal.

(3) It should be of adequate capacity and suitable form, so as to prevent road detritus, sand, &c., entering the sewers.

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[1] *Sanitary Institute Journal*, vol. xvi., p. 466.

(4) Its outlet should be so situated as not to be exposed to the danger of fracture by steam rollers or other heavy traffic.

(5) It should not admit of being easily choked by leaves, straw, sticks, paper, &c., being washed into it; and should not exhibit dirty surfaces upon looking vertically down into it.

Good modern forms of street gullies possessing the above essentials are—Sykes' circular street gully,[1] and Doulton's improved street gully. The "Crosta street gully,"[2] made of cast iron, is also good.

Street "Orderlies."—What is known as the "orderly" system consists in the provision, for day-work, of boys or men at regular intervals along the main streets and secondary thoroughfares. Their business is to keep the streets free from horse-dung and other litter made by the traffic; and, for the reception of the sweepings, ugly cast iron bins are frequently placed at the edges of the footways, and emptied periodically during the course of the day into the scavenging carts whilst on their rounds. The bins afford considerable obstruction to pedestrians, and are sometimes used by adjoining occupiers as receptacles for their house, shop, or other refuse. As a substitute for the bins, the "orderly" men should be furnished with suitably-made *hand trucks*, which are free from the above objections, and, in addition, they assist in keeping the sweepers at work, as they cannot be left unattended on the roadway. They are emptied into the scavenging carts as before.

The surfaces of paved roadways is also kept cleared of "slop" by the "orderly service boys" using "squeegees."

Machine Sweeping.—Town streets are cleansed sometimes by *hand-sweeping*, but more usually by means of *horse brooms*. The amount of work done by the latter, as compared with manual labour, is about as 11 to 1, showing a very considerable economy in favour of machine work. "Much depends, however, upon the value of labour, and also upon the condition of the roads to be dealt with; but in point of time, and as a general rule, the value of a horse rotary brush-sweeping machine is undoubted; the only time at which such a machine fails to do effective work on a macadam road is on the occasion when the mud to be removed (owing to a peculiar condition of the atmosphere) has attained a semi-solidity, and is of a stiff and sticky consistency, when it either adheres to and clogs the brushes of the machine, or is flattened by them on to the road instead of being removed. The brushes of a machine last about 180 hours' continuous work, and then the old stocks can be easily refilled with bass at no great cost.[3]

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[1] Manufactured by the Albion Clay Company.

[2] Manufactured by the Patent Gully Company, Nottingham.

[3] "Municipal and Sanitary Engineer's Handbook," by P. H. Boulnois, C.E.

Scraping macadamised roads by machine and rotary brushes drawn by horses will be found 33 per cent. cheaper than hand scraping, and equally effectual.[1]

Brooms.—Bass brooms are preferable to birch. In order to test the quality of a broom, it may be soaked for a few days in water before being given out for use, upon which its durability should be noted. The handles are best made of alder wood.

In Chelsea the *cleansing of wood pavements* is effected in the following manner:[2]—

"In addition to the regular street orderly service, the wood pavements are washed once or twice a week, and are cleansed daily either by horse-sweeping machines or by hand labour. In the absence of heavy rains, mere sweeping fails to keep wood pavements clean, and *washing* then becomes essential. To effect this, water-vans are sent out before midnight, and the surface is so thoroughly soaked that, by the time the sweeping machines commence to work at 3 a.m., the dirt is easily removed, the entire operation being concluded in the forenoon. The ascertained *cost* of this service, including labour and horse hire in washing and sweeping, street orderly work, and collection and removal of the sweepings, amounts to 4½d. per square yard per annum, as against 11d. per square yard for macadam previous to the substitution of wood;" that is, the proportion between the cost of cleaning *wood* and *macadam* is as ·41 : 1·00.

Cleansing by Washing.—The *washing* of footways and carriageways paved with asphalt, wood, or granite, by means of hose and hydrants, was first tried by Mr. T. Lovick about 1850. In his experiments in washing the streets of London he found that when working at "extremely low pressures" rather less than *one gallon of water* was required *per square yard of surface* for cleansing, whilst Mr. Lee, in experiments at Sheffield, with "very high pressures," found a consumption of less than *one-third of a gallon per square yard* to be sufficient. Footpaths, Mr. Lovick estimated, could be cleansed with half a gallon per square yard, and the total cost for street cleansing by washing would be 5d. per square yard per annum, or £20 16s. 8d. per 1000 square yards per annum.

Experiments were also made in 1867 and 1872 in washing the streets of London—"hydrants were erected in Cheapside, at distances of 133ft. apart, and in Old and New Broad-streets, at 140ft. apart. Six men were employed at each washing of Cheapside in the first trial, and ten men in the second trial; for which two jets of water were used during the time of the first trial. The work of the ten men in the second trial was thus distributed: four in playing the jets, two in moving the hose from place to place, and four with brooms in sweeping the surface of the asphalt and keeping the channels free from straw and larger refuse. These men also used 'squeegees' (india-rubber sweeps) to dry the surface of the asphalt. Of the six men employed on the granite pavement (Cheapside), four played the jets and two moved the hose and plied the brooms. The granite pavement was more thoroughly cleansed by hose than in the ordinary way by scavengers. The cost of washing asphalt was only 8 or 4 per cent. less than that for granite."[1] The following are among the results obtained:

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[1] *Vide* "Proc." Inst. C.E., vol. lxxviii.

[2] "Proc." of the Association of Municipal and County Engineers, vol. xii.

Description.	Granite pavement Cheapside, 1867.	Asphalt pavement, 1872.	
		Cheapside.	Broad-streets.
Area washed per hour, in square yards	4220	5000	8500
Water consumed per square yard, gallons	1·99	1·90	2·66
Total cost per square yard per annum, including labour, water, supervision, and depreciation of plant—pence...	9·010	8·200	11·831

Average cost per square yard per annum 9·68 pence.

The late Colonel Haywood gave the cost of washing in the City of London as being about 8½d. per square yard.[2]

The washing of wood, granite, and asphalt paved surfaces is now very successfully adopted in several London parishes, and it is certainly the most sanitary mode of cleansing that can be employed. Its advantages to the public health cannot be over-estimated, especially in courts and alleys, some of which are washed down two or three times weekly.

A washing gang is comprised of three or four sweepers, one turncock, and one nozzle-man; the latter, attending to the hose and directing the water on to the carriage ways, is followed by the sweepers with india-rubber "squeegees." The work is performed during the night when there is little or no traffic.

The objection sometimes raised against the system of washing, to the effect that ballast is washed into the sewers, is obviated by the provision of suitable trapped street gullies as described above, and the regular washing of streets also very usefully assists in flushing the sewers, and thus freeing them from deposits.

The more important streets of Paris are cleansed by washing daily; in the main streets and boulevards this is effected by the hose attached to street hydrants. The lesser streets are washed twice or thrice a week by water carts.

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[1] Law and Clark's "Roads and Streets."

[2] *Journal of the Sanitary Institute*, vol. xvi.

DISPOSAL OF STREET REFUSE.

The disposal of *street refuse*, like that of *house refuse*, is daily becoming a more difficult, and expensive operation in almost all thriving centres of population. The difficulty mainly arises from some or all of the following causes :—

(1) The absorption of refuse "shoots" by extensive building operations, thus necessitating the cartage of "slop," &c., to greater distances for disposal.

(2) The increase in the area to be scavenged, through the dedication or taking over from time to time by the Authority of private streets with a proportionate increase of traffic, and therefore necessarily an increased quantity of street refuse.

(3) The necessity for a more efficient and thorough system of scavenging through the altered character of the district from a rural to a thickly-populated urban area.

The simplest, cheapest, and therefore most popular method of disposal of street slop and refuse, is to shoot it upon any waste land —such as marshes, shallow estuaries, or sea foreshores—that may be available for the purpose within a distance such that the cartage or carriage by rail or water would not be prohibitive; the land so treated ultimately acquiring an increased value owing to its being made available for culture, and in some cases even for building purposes, a practice which must be condemned upon sanitary grounds. In London the street refuse is chiefly barged away and utilised in filling up waste land.

In some districts the street sweepings are disposed of by selling to farmers, market gardeners, and others for agricultural purposes. In Liverpool the dry sweepings only, from paved streets, are thus sold. Some authorities in small country districts allow market gardeners to themselves remove sweepings from the streets, but when not so taken are then tipped with the house refuse.

The Vestry of St. Mary, Newington, dispose of slop, &c., in the preparation of what is known as "Newington Mixture." The process of manufacture is as follows :—Upon the surface of a paved and guttered yard stable manure and "soft core" are shot, forming a hollow square, into which, as into a sort of tank, the slop, mud, &c., are deposited until about half full. This is then left for some days, in order that the water may drain off, when the tank is filled up with stable manure and soft core and the whole is well mixed and sent to one of the Vestry's country depôts by rail, and there awaits sale to farmers. The sale is said to be "regular, orders being booked several months in advance, and the price, 8s. to 8s. 6d., tends to rise, while it is stated that poor lands, letting at no more than 12s. the acre, have by its help yielded crops equal to the best."[1] In some of the Northern towns of England where the "pail system" is in use, a saleable manure is produced by the mixture of the night-soil with street sweepings and dust. The Liverpool Corporation dispose of a large proportion of their refuse and slops by sending it to sea in steam hoppers; a small, portion, however, consisting of sweepings from paved streets, stable manure, and fish offal, is shot into barges and sold to farmers along the canal banks for agricultural purposes.

Writing in 1885, Mr. T. De Courcy Meade, M. Inst. C.E., states that, "In this district (Hornsey) some of the cleanest road drift is utilised for binding the metal on macadamised roads, but it does not answer the purpose so well as hoggin. From observations I have made, I find that the steam roller can perform from 10 to 20 per cent. more work when hoggin is used; it also makes a cleaner and more durable road, as the macadam binds more readily, and consequently the stones retain their angular form. In warm weather the smell from the road drift has been the cause of complaint, therefore its use had to be discontinued."

Islington Washing Process.—The Vestry of the Parish of St. Mary, Islington, have a process of *washing the street refuse* in operation at their Depôt adjoining the Great Northern Railway Company's sidings at Holloway, the *sand* derived from which is used for roadmaking, and the surplus is sold. "There are three wash mills, about 20ft. in diameter, worked alternately by a 12-horse power engine. The quantity of slop, &c., washed per week is on an average about 600 yards. The mills are said to be capable of washing about 120 yards of slop per twenty-four hours, for which purpose about 36,000 gallons of water are required. This quantity of slop would give a residue of about 20 to 25 yards of clean, sharp sand, suitable for building purposes. The "skimmings" and "sludge" are mixed with stable manure, or dustbin refuse; the liquid result is carefully passed through settling pits or tanks, from which a comparatively clear effluent is run off. Some of the sand is used for roadmaking, and the surplus sold at 3s. per yard. Formerly the slop was calculated to cost the Vestry, on an average, about 1s. per yard for disposal; by the washing process the net *loss* is said to be about 2½d. per yard."[2]

The disposal of street and house refuse in *Kensington* entails a heavy expenditure, as will be seen from the following description of the scavenging work of that district[3] given by Mr. W. Weaver, M. Inst. C.E., surveyor to the Vestry.

"For the purposes of *road scavenging* the parish is divided into ten districts; 164 *scavengers* are employed, and there are also eleven *horse-brooms* and eight horse *road-scrapers* used.[1] The main roads are swept during the night, and the carts commence removing the slop at 6 a.m.; the gullies in these roads are also emptied and disinfected in advance of the slop carts. In the winter 6 *sand distributors* are employed to assist manual spreading, and whenever necessary the roads are sanded at night. The road refuse from the south section of the parish is carted to the wharf at Chelsea and barged away at a cost of 1s. 4d. per cubic yard. At present the northern road refuse is shot into brickfields, the Vestry paying 1s. and 1s. 8d. for each load shot. The total number of loads of refuse removed from roads and gullies during the past year (1891) was 45,458." Mr. Weaver has reported to his Vestry on the advisability of erecting a destructor for consuming the non-saleable part of the house refuse, suggesting the employment of the waste heat for working machinery for *washing* the refuse from flint and macadam roads, and for the generation of electricity. He also considers that no better material than the *grit and sand* obtainable from the road sweepings can be desired for the wood paving when slippery, or for the consolidation of the roads, and that it could be readily sold for 8s. 6d per yard.

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[1] "Health Officers' Pocket Book," by Dr. Willoughby.

[2] Report on "Scavenging," &c. (1885), by Mr. T. De C. Meade.

[3] "Proceedings" of the Association of Municipal and County Engineers, vol. xviii.

Snow Removal.—This is a duty which, when a heavy downfall of snow occurs, throws considerable pressure upon the department of the official responsible for its removal. *Promptitude of removal* is the chief object to be aimed at in successfully dealing with a snowfall, as if allowed to lie it soon becomes trampled hard upon the pavements and has then to be hacked or scraped off at considerably increased trouble and expense.

From experiments of Prof. Clericetti and Mr. E. B. Sormani, the city engineer of Milan, it has been shown that a *cubic yard* of fresh-fallen snow varies in weight from 70 lbs. to 815 lbs. Taking the average weight of a cubic yard at 442 lbs., or ·198 ton, then for a fall of 8in. of snow upon a *mile* of roadway 40ft. in width there would be a quantity equal to $\frac{5280 \times 40 \times \frac{1}{4}}{27} \times \cdot 198 = 387$ tons to be cleared away and disposed of.

Formerly within the metropolitan area the occupiers of the adjoining property were responsible for the duty of clearing the snow from the *footpaths* opposite their premises, but this work now (since the passing of the Public Health (London) Act, 1891) devolves upon the Local Authorities — a plan which, although throwing increased responsibility upon public officials, is undoubtedly the most satisfactory for securing uniformity and efficiency in the work.

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[1] This staff is now (July, 1897) increased to 170 scavengers, 86 orderly boys, 12 horse-brooms and eight horse road-scrapers, and the parish, which has 86 miles of public streets is now divided into eleven districts for scavenging purposes, a ganger receiving 30s. per week being placed in charge of the men of each district. Sweepers are paid 21s. per week; orderly boys 1s. 6d. per day.

Snow is either removed (*a*) by means of sweeping and carting away, or (*b*) by sprinkling salt upon the roadway and washing off the resultant liquid. Mr. Boulnois (Liverpool) writes,[1] "In order to grapple with this question of the removal of snow, I am of opinion that it is useless to attempt to cart it away while falling, but try to make clear crossings for the foot passengers and to keep the traffic open. If there should be a high wind at the time, and the snow drifts in consequence, cut through the drifts so as to allow the vehicular traffic to continue. Directly the snow ceases to fall, put on all the available hands to clear the channels, gutters, and street gratings, in preparation for a sudden thaw, when, if these precautions were not taken, serious flooding and great damage to property might ensue; for the same reason cart away all the snow you can at the bottom of gradients and in the valleys, and also from very narrow streets and passages, &c. In the wider streets use the *snow plough*, or with gangs of men — in the snow season there is generally plenty of labour obtainable—shovel the snow into a long narrow heap on each side of the street, taking care to leave the channel, gutters, and gratings quite clear, and a sufficient space between the heaps for at least two lines of traffic. Passages must also be cut at frequent intervals through the heaps, in order to allow foot-passengers to cross the street, and also to let the water reach the channel gutters as soon as the snow begins to melt." All the details of organising the successful clearance of a snowfall should be cut-and-dried beforehand, and be in perfect readiness for use at a moment's notice.

The use of salt for assisting in the removal of the snow should not be resorted to if it can be avoided; and it is only needed when the snow has been allowed to *lie*, or when it is impossible to deal with it by carting. Salt mixed with snow produces a freezing mixture, which, owing to its peculiar chilliness, is dangerous to the health of pedestrians, and harmful to horses, &c., so that its use should be confined to night work, and the resulting slush immediately removed. Dr. E. F. Willoughby, M.D., says,[2] "The intense cold produced by the melting of the snow with salt does not, it is true, persist long, the brine acquiring in a short time the temperature of the air; but apart from the immediate danger of chill, boots into which it penetrates cannot be dried, the salt absorbing moisture for an indefinite period. The practice cannot be too strongly deprecated, and if it must be resorted to for the purpose of melting hardened snow, the slush should be completely removed by copious washing and mechanical sweeping, followed by a liberal application of sand and gravel."

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[1] "Municipal Engineers' Handbook."

[2] "Health Officers' Pocket Book."

In Paris salt is spread as soon as the snow commences to fall, and after about four or five hours the liquid mixture resulting is machine-swept from the roadways, and removed with squeegees from the foot-paths. The surfaces are then flushed with water and the slush swept into the sewers. This method cannot be applied to macadam surfaces, owing to the large amount of detritus which would be carried into the sewers, but may be used upon wood, asphalt or granite paved streets.

As an example of the enormous amount of extra work devolving upon the responsible authorities consequent upon heavy snowfalls may be mentioned the following particulars (from statistics by the late Engineer to the City Corporation) of the snowfall of 1881, which reached a depth of 6in. to 7in.

"The removal of this fall of snow from the City necessitated the employment of 1287 hands, and 288 horses and carts,[1] the number varying slightly day by day. The work of clearance continued day and night by relays of men and horses, and continued for a whole week, during which time no less than 70,445 cubic yards of snow were removed, estimated to represent a *quarter of a million* cubic yards measured as it lay after the fall. The additional cost of this work over and above wages of regular staff was £4254."

The ultimate *disposal of snow* is oftentimes a question equally difficult with that of its removal from the street surfaces. Tipping down manholes into the sewers has been tried, but the snow consolidates, and although artificial heat, as gas jets, has been applied, the melting has been too slow to be of much use.

Should there be a river conveniently near the town the snow may be shot into it; but there will be the objection to this, in the case of a navigable river, of the silting up of its bed with the road detritus unavoidably removed with the snow.

Public parks, recreation grounds, or waste pieces of land may oftentimes be found available for the deposit of the snow, provided the distance is not prohibitive for purposes of cartage.

Clarke's apparatus is designed for the melting of snow, and is said to cost about £120 fixed—the cost of melting being given at 9d. per cubic yard. Mr. Haywood, in reporting to the Commissioners of Sewers in 1881 upon this method of disposal, states,[2] "It is seldom that a fall of snow occurs sufficiently large to cause serious interruption to the traffic; heavy snowstorms, in fact, occur only once in six or seven years. For some years, therefore, these apparatuses if fixed might not be required. They would either have to be taken out, stored, and refixed yearly, or maintained in their places and kept in order there; in either case at an annual expense."

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[1] *Journal* of Sanitary Institute, vol. xvi.

[2] Report, 1881, to the Streets Committee of the Honourable the Commissioners of Sewers of the City of London on "Melting Snow by Clarke's Apparatus," by William Haywood, late engineer and surveyor to the Commission.

STREET WATERING.

Any remarks upon the scavenging and cleansing to streets would necessarily be incomplete without some reference to the important question of "Street Watering." The necessity for an efficient system of watering in dry weather is at once obvious and unquestioned. The atmosphere of the streets of large centres of population during summer would be almost unbearable were it not for the keeping down of the dust, manufactured by the traffic and raised by the wind, and the cooling and refreshing of the air by means of some regular system of watering. Also, besides the extreme general discomfort of the inhabitants, and irritation to the eyes caused by dusty streets and atmosphere, there is considerable damage done to food exposed in shops by the circulation of dust as upon a windy day, oftentimes rendering it quite unwholesome for human consumption.

There is, too, a further consideration not altogether so insignificant as to admit of being entirely overlooked, viz., the amount of damage likely to be occasioned to the clothing of pedestrians. Imagine, upon the inevitable approach of a thick cloud of dust, the almost boundless extent of the unmerciful ire aroused within the bosom of the prim and neatly attired individual of the gentler sex, pacing out, it may be, upon her morning constitutional, and perhaps exposing to the daylight, probably for the first time, some newly and cunningly devised piece of head-dress or other superb finery. Or, contemplate the personal discomfiture and general spoilation of figure and toilet, inflicted by the successive rolls of impartial dust clouds upon the all-important "city clerk" or quill-pilot "got up" with great study and elaboration of dress generally, and finished off with highly glittering hat and boots. Can anything to *him* be much more tiresome—having thus bestowed such diligent pains? His wrath will, likely, by the end of a windy week, find its safety valve in a more or less feeble composition for the next issue of the local press—hoping, and, in some cases, perhaps, even presumptuously *expecting*, that it will adequately "lay the dust" for many a coming week.

To effectually prevent any such inconveniences, and to maintain the wholesomeness and freshness of the atmosphere of the streets, are important reasons for an efficient system of "watering." The American householder, it is said, even at the present day, waters the area in front of his house by means of water bottles, every day before sunrise; whilst in India may be seen the water-carrier with a large pigskin vessel, having one of its legs ingeniously adapted as a distributor, sprinkling water upon the street surfaces.[1] An early and excellent (from a *sanitary* point of view) method of street watering was that of damming the water with leather or canvas aprons as it ran along the side channels, and then ladling it on to the roadway by means of wooden shovels. The method, though primitive, effectually washed the surface of the street, flushed the channels, gullies, and sewers, and imparted freshness and coolness to the air. The quantity of water used was very large, and the plan cannot be practised where there is much traffic.

In an excellent paper upon "Road-watering," by Mr. W. Santo Crimp, delivered at Hanley (1886), the consideration of this subject is dealt with under the following heads:—

(*a*) The quantity of water required in order to lay the dust effectively:—

(*b*) The spreading of the water by means of the most effective appliances.

(*c*) The purchase of the water on the most advantageous terms.

The question of the *quantity of water* required is, as Mr. Santo Crimp has observed, very variously affected, and depends chiefly upon:—

(1) The nature of the materials forming the surfaces of the roadways.

(2) The conditions in which the roads are kept as regards cleanliness, for the more dust allowed to remain the more water will be required.

(3) The aspect of the streets, and the absence or otherwise of trees and other shade factors.

(4) The wetness or reverse of the particular locality and its peculiar requirements.

(5) The question of finance.

"The rainfall exercises a considerable amount of influence on the question, and approximately it will be found that on days when ·08in. and upwards falls, watering will not be required, although it may sometimes occur that watering will be necessary two or three hours after the cessation of a heavy fall. Careful observation will prove that a fall of ·04in. of rain will lay the dust in a well-kept macadamised road, and also effect a very slight washing—a little water running into the gullies. That amount of rain is equal to ·187 *gallon per square yard*, which is also the usual amount spread by *vans and carts*. In seasons of prolonged drought, light washings are much to be approved, in order to remove some of the absorbed filth, and to sweeten and refresh the atmosphere."

Mr. Crimp further states that at Wimbledon he was in the habit of spreading one gallon of water over 5·2 square yards, *i.e.* ·192 *gallon per square yard at each watering*. In his district, during the summer of 1885 "the roads were watered on 182 days, and 2¼ times each day; thus, each superficial yard was watered 298[1] times, and 298 × ·192 gallons = 57·216 gallons per yard. A mile of road 24ft. in width between the curbs, contains 14,080 square yards, and 14,080 × 57·216 = 805,601 gallons, *the amount used per mile* . . . In residential districts like Wimbledon, it may be safely assumed that on an average four-fifths of a million gallons per annum will be necessary, costing at 9d. per 1000 gallons, £30, and at 10d., £33 6s."

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[1] *Vide* "Proc." Association of Municipal and County Engineers, vol. xii.

In the metropolis it is usual to allow 180 days as the average period during which the streets are watered; and at fashionable towns it is performed as necessary throughout the year.

The quantity of water used per mile[2] of roadway in different districts varies considerably, as will be seen from the following:—

St. Pancras (in 1883) used water at the rate of 438,300 gallons per mile.

Hove (1885) used about 1,250,000 gallons per mile of 14,080 square yards.

Norwich (1885) used about 514,300 gallons per mile.

Wellingboro', about 228,400 gallons.

As to the *spreading of the water*, the following are the methods which have been employed:—

Brown's System of Street Watering has been tried, but has not been very largely adopted. "A channel 2½in. in width is formed at the back of each curb, in which is laid a lead pipe. At intervals of 1ft., a small shield, having suitable perforations, is fixed, and corresponding holes are bored in the pipe. The surface is then made good with asphalte; stop cocks are provided, and on turning on the water it issues in fine jets in the direction of the carriage way, thus effecting the desired purpose." Its main objections[3] are that "while the water is turned on, pedestrians cannot occupy any portion of the curb or roadway; that the jets rising 3ft. to 4ft. above the roadway may be a cause of inconvenience to the traffic; and that the effects of high winds when the pipes are laid on one side only (as in the case of narrow roads) would be to seriously interfere with the proper watering of the streets; that in very wide streets it would be necessary to water the central part with carts." The width of carriage way which can be watered by this plan necessarily varies with the pressure of the water.

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[1] 132 × 2¼ = 297, not 298 as text.

[2] This will obviously depend upon the width of roadway. For detailed statistics, see Appendix to Mr. W. S. Crimp's paper on "Road-watering" in the "Proc." of the Association of Municipal and County Engineers.

[3] Report of a trial of the system by Mr. H. T. Tomkins, surveyor to the St. Marylebone Vestry.

The Paris System.—In this, "the distribution of the water is accomplished by means of a series of short lengths of very light galvanised iron pipes, joined by short pieces of leather hose, thus allowing the whole length in use to be turned into any desired direction when mounted on the light trucks or carriages forming part of the system. A special distributor is fixed at one end, and the other being attached to a hydrant, water is applied in any direction, and in such quantities as may be desired within the limits of the machine. The apparatus is constructed in a very light and portable form, and is especially suitable for washing the paved surfaces of streets and alleys, also for ordinary watering, and in situations where carts or vans are inadmissible."[1]

The experiments made by Mr. Lovick in 1850, upon the cleansing of street surfaces by washing, have already been referred to under the head of "Scavenging."

The Hose-reel. — Headley's hand machine consists of a suitable length of flexible india-rubber hose, wound upon a large drum or reel fixed in a frame, and mounted on a pair of wheels. The hose, having been connected to a stand-post or hydrant, distributes the water through a spreader; and as the machine is moved onwards in the course of the process of watering, the hose unwinds upon the ground—a circumstance which renders the system ill-adapted for busy streets. On the working of this method in Tunbridge Wells, Mr. Brentnall has stated that "the system is very easy and simple in application, and very superior and preferable to carts. The latter are only used when the pressure, which varies from 40ft. to about 326ft., is not equal to the work. The hose is of india-rubber, three-ply, 1in. in diameter, and lasts five years. The water is taken by means of a standpipe, of special construction, from Bateman and Moore's fire-cocks, which are placed 75 yards apart. The cost of the complete apparatus is £25. The average work performed per day of ten hours by a *cart* and by a *hose-reel* is as follows :—

Man, water-cart, horse.	*Man, boy, hose-reel.*
19,860 superficial yards. 7700 gallons water.	19,860 superficial yards. 9100 gallons water.
9s. cost, inclusive of repairs, renewals, &c.	6s. cost, inclusive of repairs, renewals, &c.

The above areas are watered twice daily; therefore, the quantity of water spread per superficial yard at each watering will be ·193 gallons in the case of the cart, and ·229 gallons in that of the hose-reel."

According to the experience of Mr. A. W. Parry, A.M.I.C.E., at Reading, a Headley's hose-reel machine will spread water at the rate of ·65 gallons per square yard at each watering, as compared with ·25 gallons spread by water-carts.[1]

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[1] *Vide* "Proceedings" Association Municipal and County Engineers, vol. xii.

Mr. Francis C. J. May, A.M.I.C.E., in a paper (March, 1888) entitled "A Review of the Sanitary and other improvements in the Borough of Maidstone during the last ten years," states that watering by hose and reel has been tried at Maidstone and proved a failure; also, that Odam's system of street watering by jets was well tried, and not being successful, was abandoned. Four-wheeled *vans* were recommended by him as being more economical than the 220-gallon water *carts* then in use.

Carts and Hydrostatic Vans.—This is the most customary method of street watering in this country. The water is distributed, by virtue of the head of pressure of the tank of water, through a perforated pipe fixed horizontally at the rear of the van or cart, and is thus spread over the roadway surface as the apparatus is drawn forward by a horse. Circular *barrels* fixed upon wheels, water *carts*, and water *vans* have each in turn come into use upon this plan, the latter having now come into general favour owing to the increased economy and efficiency with which it performs the work. The van for once filling will water almost double the distance that can be done with the cart, thus effecting a considerable saving of time in travelling to and from the stand-posts. Carts, however, are preferable for working steep gradients.

The following useful observations upon carts and vans are given by Mr. Santo W. Crimp in his paper[2] on "*Road Watering*," previously referred to. He states that "the width watered depends, not so much on the mere size of the tank as upon the head of water on the distributing pipes, and the sufficiency of these to allow the full force of the head to be utilised. The velocity of the issuing jets, and, approximately, the distance to which the water will be projected, *varies as the square root of the head.* The distance is also influenced by the size of the holes, and by the direction in which they are drilled; also by the height of the distributing pipe above the surface of the ground, and there is no reason why a van should water a greater width than a cart, if the latter is properly constructed. An interesting diagram of the paths of jets may be plotted, say, under heads of 2ft., 3ft., and 4ft., issuing at different degrees of obliquity. With the spreaders fixed 2ft. above the ground, an angle of 40 deg. will give the greatest projection. Under such conditions, a theoretical width of 25ft. may be watered with a full head of 4ft.; while with the head, due to the tank being nearly empty, say of 2ft., a width of 16ft. only is watered. In practice the author finds, taking the mean of several vans, that the widths are 18ft. when full, and 12ft. as just empty. The resistance of the air breaks up the jets, which in consequence do not reach to nearly the theoretical width.

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[1] *Vide* "Proceedings" Association Municipal and County Engineers, vol. ii., page 152.
[2] *Ibid.* vol. xii., page 238.

"The variation in the width watered, as the van becomes empty, is well known to surveyors, and attempts have been made by means of valves to regulate the width. But, in order to do so, the width due to the minimum head can only be maintained, and the loss of time consequent upon the throttling of the water would not compensate for any advantage thus accruing. A side spreader, of complicated construction, could be adopted also. In that case the spreader must revolve slightly as the van becomes empty, so that the water issues in a horizontal direction at first, gradually changing until the finish, when it should issue at an angle of 30 deg. When the nature of the appliances necessary for effecting the object is considered, it will be admitted that no commensurate advantages will result from their adoption.

"A considerable width of spread has been attained in *Willacy's patent cart*, by the adoption of horizontal rotating spreaders, operated by the wheels of the cart, in connection with a chain driving band. As the cart or van proceeds, the spreaders revolve, throwing the water to a considerable distance on each side. It is stated that this apparatus will water a width of 33ft.! The spreaders are also constructed with large holes for distributing sand on the streets in frosty weather.

"The amount of work that may be performed per diem with a cart or van will be mainly dependent on the pressures in the mains, since the periods occupied in emptying and in travelling, both when empty and full, may, with properly arranged stand-posts, be reduced to a nearly common standard. With pressures such as should obtain in an efficient system of water supply, the vans of 460 gallons should be filled in four minutes at most; six minutes will be occupied in discharging the contents, and about ten minutes in travelling full and empty, and in getting into position for refilling; thus three van loads per hour may be distributed. With exceptionally good pressures, and close contiguity of the streets watered, the author has found that 96,000 square yards may be watered with 18,482 gallons of water per day of ten hours; but the average amount of work performed in his district is the spreading of 13,824 gallons on 72,000 square yards with a *van*, and 10,100 gallons on 52,600 yards with a *cart*; but with very low pressures, the difference between the amount of work performed by a van and by a cart will not be so great. Although a van waters an area nearly one-third n excess of a cart, it uses a proportionately greater amount of water, and the *total saving* does not exceed about 16 per cent.[1]

"In the author's experience, a *van* waters 2400 square yards each time of filling, spreading the water at the rate of ·192 gallons per square yard, the average width being 5 yards and the length 480 yards. The horses and vans are the property of the Local Authority, and the cost, including horse, driver, and van, is 8s. 8d. A *cart* costs, with all charges, 7s. 10d. The watering of 1000 square yards once costs 1·87d. with a van, and 1·78d. with a cart; the water at 10d. per 1000 gallons costs 1·92d., and the total costs are: *van* 3·29d., *cart* 3·70d. Although a van waters a much greater area than a cart, the total saving as indicated by these figures is only about 11 per cent., while the saving, not including water, is about 23 per cent.; in short, with dear water, the saving is proportionately less than with cheap water."

The water is conveyed from the mains into the vans either by means of a hose with coupling for attachment to the fire hydrants, or by fixed stand-posts with swivel swan necks. These latter are preferable, and should be so arranged at such intervals as will avoid waste of time in going to and from the work.

As to the *purchase of water used in street watering* there are several methods adopted, *e.g.*:—

(1) Paying for the quantity used as gauged by a meter fixed at each stand-post. This seems to be the fairest and best method.

(2) Payment according to records of "tell-tale" fixed in each cart or van.

(3) Payment at a fixed charge per van used.

"Where water is charged for at a rate per 1000 gallons, the cost varies from 1½d. at Basingstoke to 1s. 8d. at Camberwell. In many of the London districts a sliding scale is adopted, the price varying with the height to which the water has to be pumped, elevated districts paying more than those at a lower level."

In the parish of Kensington there are three Water Companies, all of which take their supplies from the Thames; and their *charges for road watering* are[2]—

The Grand Junction Company, ¾d. per square yard of road surface, less 20 per cent. discount.

The West Middlesex Water Company, 5s. per 100 superficial yards, less 17½ per cent.

The Chelsea Waterworks Company, 5s. per 100 superficial yards, and 30s. each stand-post.

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[1] *Preston Chronicle*.

[2] *Vide* "Proceedings" of the Association of Municipal and County Engineers, vol. xviii. p. 85.

In the district of Hornsey "the water required for street watering is supplied by meter. The readings of the meters are taken at the end of each season, and payment is based upon the result, at the rate of 1s. per thousand gallons, less discount, varying from 3 to 6¼ per cent., according to thequantity of water consumed. In addition to the above, an annual rental of £2 2s. per meter is charged by the New River Company."[1]

The use of *sea water* for street watering in seaside towns is now largely adopted, and with very advantageous results. It is more effective than fresh water—one load of sea water being equal in efficiency to three loads of fresh; and, where it can be economically pumped, it will be much cheaper than water obtained from the town mains.

"The soluble salts are left on the surface watered when the water has evaporated, and by taking moisture from the atmosphere or from the subsoil when required, humidity is maintained for a period dependent on the amount of the salts, and on the hygrometric conditions of the atmosphere.[2]

The following are the *objections* which have been raised to its use:—

(1) That it is detrimental to the road surfaces.

(2) That it is detrimental to tradesmen's goods in adjoining shops.

(3) That it assists decomposition of organic matter on road surfaces.

(4) Possible damage to horses' hoofs, carriage varnish, wheel tires, &c.

The testimony of those having had considerable experience in the use of this water is to the effect that these objections are groundless, and Mr. Boulnois, in speaking upon this question,[3] gives his unqualified approval to the use of sea water for sprinkling roads and for sewer flushing.

Chlorides of calcium and of sodium have been mixed with water for road watering, in the proportions of 8 oz. to 16 oz. per gallon of water.

Mr. Boulnois states that in Rouen, where chloride of calcium is obtained from the manufactories of pyroligneous acid in the neighbourhood, it is mixed with the water for use on the roads, the humectation lasting for five or six days.

In warm weather, and upon the occasion of epidemics, streets are frequently watered with a largely diluted *disinfectant*—a very desirable practice in the crowded and poorer portions of a district.

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[1] Report on "Scaverging," &c., by Mr. T. De C. Meade (1885).

[2] "Proceedings" Association Municipal and County Engineers, vol. xii., p. 243.

[3] "Municipal Engineers' Handbook."

Mr. Charles Mason, A.M.I.C.E., surveyor, St. Martin's-in-the-Fields, mentions[1] that in his district a mixture of manganate of soda, sulphuric acid, and water is used in the following proportions:—

Manganate of soda	1 lb.	To 100 gallons of water in the van.
Sulphuric acid	½ pint	
Water	1 gallon	

The mixture is said to give a feeling of increased freshness to the atmosphere.

In busy thoroughfares the first watering is usually done at an early hour of the morning previous to sweeping, after which the streets are again watered and the process repeated throughout the day at convenient intervals, and as found necessary. If, in the early morning, those streets lying north and south be watered before those extending east and west, thus taking regard to the incidence of the sun's rays, some economy in watering may be effected.

Speaking generally of the important operations of scavenging, street cleansing, and watering, hard-and-fast rules as to the mode of its execution cannot be laid down, but must necessarily vary with the nature and facilities, or otherwise, of the district to be dealt with. The increasing difficulty, however, of getting this work *efficiently* and satisfactorily executed under the contract system makes it most desirable that it should be performed by the Local Authority with their own officers and staff. On this question, Mr. Boulnois, City Engineer of Liverpool, writes: "It is, perhaps, true that this work may be done by contract at less actual cost to the ratepayers; but all public work should be done in the best manner possible, irrespective of cost, thoroughly, but without extravagance; and the result of such work, especially where it affects the cleanliness and the appearance of a town, soon fully repays any moderate extra cost that may thus have been incurred, irrespective of the enormous benefit that is conferred upon any community by the reduction of disease and the death-rate, by a proper attention to such necessary sanitary work."

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[1] *Vide* "Scavenging: Disposal of Refuse" (November, 1895). *The Sanitary Institute Journal*, vol. xvi., p. 470.

CHAPTER II.

HOUSE REFUSE: ITS COLLECTION AND ULTIMATE DISPOSAL.

DEFINITION OF REFUSE, ITS COMPOSITION, QUANTITY, &c.

"*House Refuse*," as has already been pointed out, is defined by the Public Health (London) Act, 1891, as consisting of ashes, cinders, breeze, rubbish, night soil, and filth; but does not include "*trade refuse*," which, within the scope of the same statute, means the refuse of any trade, manufacture, or business, or of any building materials.

The Public Health Act of 1875 does not define what *is* "house refuse;" and questions have consequently arisen as to what articles should be removed by the Local Authority. To assist in the business of collection, some Authorities have issued cards to the householders within their district, containing information upon the following lines as to what substances are and are not to be removed as *house refuse*, and which may be taken as fairly indicating what may be included within that term: "It is hoped that householders will, as far as possible, facilitate the systematic removal of refuse by providing suitable dust-bins, and directing their servants that *ordinary house refuse only* shall be deposited in such receptacles. The following are some of the items of refuse which the contractors are bound to remove, viz.: Cinder ashes, potatoe peelings, cabbage leaves, and kitchen refuse generally. But the contractors are not required to remove the refuse of any *trade*, *manufacture*, *or business*, or of any building materials, or any garden cuttings or sweepings."

Trade Refuse is usually removed by the Authorities upon payment of a reasonable sum for so doing. In the metropolis the charges made for such removals vary from two to five shillings per load. This class of refuse necessarily differs widely in different localities, but may be taken as usually consisting more or less of furnace clinker and ashes, shavings, waste paper, and packing materials; also of the refuse of the trades of greengrocer, poulterer, butcher, and others.

Amongst the articles which frequently find their way into the domestic dust-bin, and the removal of which may well be objected to by the scavengers of a Local Authority as not being within the meaning of the term "house refuse" in the Public Health Act, are the following[1]:—

1. Plaster from walls and brickbats;

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[1] "Municipal Engineers' Handbook." (Boulnois).

2. Large quantities of broken bottles and flower pots;

3. Clinkers and ashes from foundries and greenhouses;

4. Wall paper torn from the rooms of a house;

5. Scrap tin (but not old tins which have contained meat, &c., and which, although very useless and bulky, may fairly be assumed to be house refuse);

6. All garden refuse, such as grass cuttings, dead leaves, the loppings from trees and shrubs.

To absolutely refuse the removal of limited quantities of "*garden refuse*" from houses having the ordinary small garden plots attached would doubtless be an unnecessarily stringent policy; but the gratuitous removal of large quantities of such, or of any kind of "*trade refuse*," would not only lead to an imposition upon the scavenger, but also be unjust to the general public.

The Composition of House Refuse. — The composition of house refuse is found to vary considerably in different localities, depending largely upon the condition, habits, and pursuits of the people; also upon the scarcity or otherwise of coal, upon the use of other kinds of fuel, and upon the nature of the district, whether of a high-class *residential* character, or a thickly-populated *business* area. "Where coal is cheap," writes[1] Mr. Codrington, "a larger proportion of cinders and unburned fuel might be expected; but this is not always the case. People who burn their own coal are generally less wasteful than a higher-class population at the mercy of servants; and this is often shown in different quarters of the same town. The superintendents from several large towns, who visited with me a dust-yard near the West End of London, expressed surprise at the large quantity of cinders and coal in the refuse. In Glasgow, on the other hand, there is said to be most cinders in the ashes from the poorer classes of the city. In summer the quantity of vegetable refuse is larger, and there is less of cinders and ashes; so that the refuse is damper than in the winter. Where uncovered ashpits are allowed, the contents get sodden with wet in rainy weather, especially if they are not cleared frequently."

There is but little doubt that house refuse is year by year becoming a more valueless material, and more difficult of disposal, owing very largely to its containing less combustible material—a result of the more general use of gas stoves, and of the introduction of firegrates effecting improved combustion—and increased quantities of hard core in the shape of tins, bottles, &c., derived from the growing consumption of preserved meats, vegetables, and fruits, thus reducing the proportion of organic refuse, and lessening the value of house refuse for agricultural purposes.

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[1] "Destruction of Town Refuse." (Report to Local Government Board, 1887).

The following heterogeneous list is given[1] by Mr. Boulnois, as showing some of the numerous articles and materials which go to make up that curious commodity—if it may be so flattered—usually known as "house refuse:" "Ashes, cinders, unconsumed coal and wood, paper of all kinds, and even books (old and new), rags, and articles of clothing of every description, immense quantities of corks (telling a sad tale !), tea leaves, eggshells, and shells of oysters and other fish, large quantities of vegetable refuse, and decayed and even sound fruit, varying with the seasons; dead animals of almost all species; meat tins, empty and full, of every description; old iron of all kinds—saucepans, baking tins, knives, forks, spoons, umbrella wires; bones of every description; fish-heads and entrails; portions of poultry, feathers, and offal of all kinds; crockery (both sound and broken), jam pots preponderating; broken glass and bottles, the latter sometimes whole, and even full in the case of medicine (but not of beer or wine !); packing cases, straw mats, carpets, table covers, pieces of leather, straps, oilcloth, and even whole mattresses and bedding, brickbats, plaster, wall paper, brooms, brushes, toys, and sundries of every description, even to gun cartridges and perambulators !" It may safely be assumed that the expeditious collection and sanitary and economical disposal of such a miscellaneous mass is no light duty or easy task, but affords one of the many outlets for the energy and organising ability of the modern Town Surveyor.

TABLE A.

Component parts.	Average per load.			Average per 1000 loads.				Percentages by weight
	cwt	qr.	lb.	tons.	cwt.	qr	lb	
Breeze (cinder and ashes)	12	0	25	611	3	0	4	63·69
Fine dust...	8	2	27	187	1	0	8	19·51
Vegetable, animal and various mineral matters...	0	3	15	44	3	3	20	4·61
Waste paper	0	3	8	41	1	1	20	4·28
Straw and fibrous material	0	2	13¼	30	18	1	6	3·22
Bottles	Number 5.			Number 5000				·96
Coal and coke	0	0	18	8	0	2	14	·84
Tins	0	0	17	7	11	2	22	·79
Crockery	0	0	11¾	5	5	0	0	·55
Bones	0	0	10⅛	4	12	1	1	·48
Broken glass	0	0	10¼	4	11	2	2	·47
Rags...	0	0	8½	3	15	3	16	·39
Iron	0	0	4½	2	0	0	20	·21
								100·00

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[1] "The Disposal of Town's Refuse." By H. P. Boulnois, M. Inst. C E.

Average *London ash-bin refuse*, according to an analysis given by Mr. Joseph Russell[1] contains the constituents in the average proportions given in Table A on previous page. Average weight per load = 19 cwts. 0 qrs. 20 lb. net.

In the Northern towns, "where the *privy-and-ashpit system*, or the *pail system*, is in use, the finer ashes are mixed with the excreta, either in the closet or subsequently, to make a portable manure, and the contents of the ashpits are generally more or less fouled with excrementitious matter. In *Manchester*, where pail closets prevail, of 1000 tons collected from the closets and ashpits in 1880, the constituent parts seem to have been as follows[2]:—

TABLE B.

Manchester refuse.	Per 1000 tons.
Ashes and excreta in pails	645·0
Dust and cinders	345·5
Fish and bones...	1·5
Dogs, cats, hens, rabbits, &c.	·5
Boots, rags, hats, paper, &c. ..	·5
Vegetable refuse	·5
Glass, pottery, bricks, &c.	6·0
Old iron and tin ware	·5
Tons	1000·0

Market refuse consists of the animal and vegetable matters, such as butcher's and fish offal, damaged fruit, &c., removed from markets, and from costermongers' stalls. "In London and some large towns the blood-boiler and drier relieves the Sanitary Authority of responsibility, since for his trade purposes he requires the blood while still fresh and inoffensive, while the fish manure, superphosphate, and chemical manure manufacturers, tallow and soap boilers, candle works, bone boilers, glue makers, &c., collect a large proportion of other animal refuse, the Local Authority having only to see that the transport of the raw material through the streets and the manufactures themselves are conducted with due care to avoid nuisances."[3]

Quantity of Refuse per head per annum.—In London, according to statistics prepared by the London County Council, the quantity of *house refuse* amounts approximately to 1¼ million tons per annum, which is equivalent to from 4 cwt. to 5 cwt. per head per annum, or to from 200 to 250 tons per 1000 of the population per annum. The statistics, however, vary very widely in different districts, and should be accepted with caution—the amount per head ranging from 1·7 cwt. in Bermondsey up to 18·8 cwt. in St. Luke's.

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[1] "Transactions" of the Sanitary Institute, vol. xiii.
[2] Report on the "Destruction of Town Refuse," by T. Codrington, M. Inst. C.E.
[3] "Health Officer's Pocket-book," by Dr. Willoughby, M.D.

In suburban districts the quantity collected also varies considerably, being at Ealing equal to 7 cwt. per head per annum, and at Hornsey 3·5 cwt. In Leyton, where the "pail system" of collection has been in successful operation for some years, the amount of house refuse collected is equal to 2·5 cwt. per head per annum; and to this is added, for the purpose of their common disposal by fire, the pressed sludge derived from the sewage precipitation works; this latter material being produced at the rate of 1·3 cwt. per head per annum.

According to figures given by Mr. G. Watson[1] in reference to the towns of Rochdale, Preston, Gorton, Bolton, and Manchester, the total house refuse collected, including pail and privy excrement (but exclusive of street sweepings) amounts to about 400 tons per annum per 1000 of the population.

Speaking generally throughout the country, an amount of from one-quarter to one-half ton per head should be allowed for.

It will thus be seen that house refuse is as variable in *quantity* as it has been shown to be in *quality*, and that there is considerable difficulty in arriving at any very definite figures as to the amount to be produced by a given population. Much depends upon the system and frequency of collection, upon the nature of the district, and the habits of the people.

In all large centres of population the bulk to be regularly dealt with is at once seen to be of enormous proportions, the satisfactory collection and disposal of which reduces to comparative insignificance even the "labours" of the celebrated Mr. Hercules, who, amongst other things, it is said, cleared away in one day the accumulated filth of thirty years from the stables of King Augeas, which contained some 3000 oxen. The above gentleman, however, apparently believing as do sanitarians of the present time, in the sanitary excellence of a *thorough flushing*, appears to have adopted the very summary method of turning the rivers Peneus and Alpheus through the royal stables, in order to effect their clearance—a process which, probably, might also be employed with advantage in the cleansing of many of the alleys and slums of our large towns of to-day. We, however, usually content ourselves with the more moderate rinsing, as afforded by the manipulation of the hose and jet.

Weight of House Refuse.—According to Mr. Codrington, a *cubic yard* of ordinary house refuse weighs from 12¼ to 15 cwt. Shop refuse is lighter, sometimes weighing as little as 7¼ cwt. per cubic yard. A *load*, by which refuse is often reckoned, varies in weight from 15 cwt. to 1½ tons.

Having considered the various *kinds of refuse* to be dealt with, their composition, quantity, &c., the points next to be discussed are :—

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[1] "The Disposal of Refuse" (a paper read before the British Association, 1892).

(*a*) Its *temporary storage* upon premises pending the collection by the scavenger.

(*b*) The methods of *collection.*

(*c*) The methods of *disposal.*

TEMPORARY STORAGE.

Temporary Storage.—House refuse must be stored, of course, in some form of *dust-bin* during the intervals of the scavenger's calls, and in order to ensure that some form of receptacle be properly installed and maintained the Public Health Act, 1875, has enacted that every "new building" shall be provided with a sufficient *ashpit,*[1] furnished with proper doors and coverings.[2] Also, that every Local Authority shall provide that all ashpits within their district be constructed and kept so as not to be a nuisance or injurious to health.[3] Local Authorities may also enforce the provision of ashpits for houses not already so accommodated,[4] and frame by-laws regulating their construction, cleansing, &c.[5]

Although the Public Health Act permits of the construction of the large brick ashpit or other form of *fixed* receptacle for dust and house refuse, they should, wherever at all practicable, be entirely abolished in favour of the portable galvanised iron bin. No town houses should be provided with fixed ashbins, as, even when built upon the most approved methods, they are unsuitable and insanitary receptacles for the refuse of ordinary dwelling-houses. They usually provide a large storage room, thus encouraging delay in collection, and permitting the vegetable and other organic refuse to ferment and decompose, causing nuisance and, most probably, danger to the public health. Such contrivances upon sanitary grounds can only be sanctioned for use in connection with large isolated buildings in country districts for hotels, schools, hospitals, &c., and where they can be fixed at considerable distances from the dwelling-houses.

"In some towns the acreage area of open dust-bins bears a perceptible proportion to the area of the town itself, and it is unnecessary to enlarge upon the evils attendant on such an insanitary condition of things. They may be suitable for hotels, schools, hospitals, and the like, but for ordinary dwelling-houses they hold too much; are difficult to quite empty or cleanse, or disinfect; and, unless there is a back passage, cause inconvenience and nuisance whilst the refuse is being removed."[1]

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[1] This term includes any ashtub or other receptacle for the deposit of ashes, fœcal matter, or refuse (53 and 54 Vict, c. 59, Sec. 11, Sub-Sec. 1).

[2] 38 and 39 Vict., c. 55, s. 35.

[3] 38 and 39 Vict., c. 55, s. 40.

[4] 38 and 39 Vict., c. 55, s. 36.

[5] 38 and 39 Vict., c. 55, s. 44.

Where fixed ashpits are provided in connection with a dwelling-house, they should, owing to the decomposable nature of their contents, be at least 6ft. distant from the nearest part of the building. Also, they should not be nearer than 30ft. distant from any source of water supply, such as a well, spring, stream, &c., "in order to protect the water from the *débris* and fine dust which so often fills the air near ashpits, when refuse is being cast into them, and also from the effluvia of decomposing vegetable matter."[2] The ashpit must be so fixed and constructed as to afford the greatest facilities for the removal of the contents of same, and so placed that the refuse may be conveyed from the premises without passing through the dwelling-house. The *capacity* should be sufficient only to contain the dust, ashes, rubbish, and dry refuse accumulated upon the premises during the period of one week; that is, of a capacity of about six cubic feet. "Frequent scavenging of ashpit contents by the Sanitary Authority should be secured in all districts having an urban character; and, apart from the desirability of its being done at least once every week, it will, as a rule, be found convenient that it should be carried out at the same intervals as regulate the cleansing of privies,"[3] where these happen to be in use from the lack of the introduction of the more efficient method of excrement removal by a system of arterial drainage. In order that the ashpit may be reasonably substantial, that the decomposition of its contents may not be enhanced by wetness, either from surface or subsoil water or rainfall, and that the removal of its contents may be rendered as easy as possible, the following points should be adhered to in its construction:—

It should be built of some impervious material, as flagging, slate, or 9in. brickwork, rendered inside with ¾in. of good Portland cement or asphalt. The floor should be kept 3in. above the adjoining ground, should have a slight slope from back to front to avoid the collection and retention of water, and should be formed of an impervious material, as stone or asphalt. The ashpit should be roofed over, ventilated, and provided with a suitable door admitting of the convenient removal of the contents, and when closed and fastened, effectually preventing the escape of the refuse. The ashpit must not connect with any drain.

In some buildings, as in those built on the principle of "flats," dust "shoots" are provided, but are very objectionable contrivances.

In order to comply with the demands of modern sanitation, insisting upon *small accumulations* and *frequent removals*, the model portable galvanised iron dust-bin has been introduced, the adoption of which, in the interests of public health, should be enforced in all districts of an urban character. The system, it is satisfactory to note, is readily growing in favour amongst Municipal Authorities, many of which have issued some thousands of portable iron bins for the use of householders in their districts. The most approved galvanised pail is provided with a tightly-fitting cover and handles, and is about 15in. in diameter and 18in. deep, holding approximately two cubic feet. For convenience of lifting, the size should not be greater than this, but where the quantity of refuse from any premises demands it the receptacles should be provided in duplicate. Perforations should be made in the sides, near the bottom, in order to prevent them being used for liquids. The initials of the owner may be formed by these perforations, and in every case the number of the house should be marked on in large figures. Some portable iron ashbins are made of larger size, fitted with cinder-sifters, and mounted on wheels, but these are not suitable for ordinary dwellings.

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[1] "The Disposal of Town's Refuse." By H. P. Boulnois.

[2] Knight's "Annotated Model By-Laws."

[3] Knight's "Annotated Model By-Laws."

The small galvanised iron pail is anticipated in the London County Council's by-laws,[1] which provide for "one or more movable receptacles sufficient to contain the house refuse for a period not exceeding one week," and specify that the receptacles "*shall be of metal, provided with a cover, the capacity of each not to exceed two cubic feet.*"

The plan of storing refuse in *sacks supported on iron frames* has proved a failure, and cannot be recommended. The sacks soon wear out, and are difficult to empty and cleanse.

Another means of temporary storage is by the provision of *public dust-bins*. "These are placed in suitable localities by the Sanitary Authority of the district, and the householders in their vicinity can place their refuse in these receptacles, which are cleared from time to time by the Authority. This is a very useful system in the poorer and more densely-populated districts of a town, and were it not for the objections which are raised sometimes by the occupiers of adjacent houses to the dust-bins being fixed in their neighbourhood, this system might be extended with advantage."[2]

COLLECTION.

Methods of Collection of House Refuse.—It has already been shown that for sanitary reasons the collections of house refuse should be as frequent as possible. Notwithstanding the difficulties occasionally raised as to the inaccessibility of the dust-bin or the unwillingness of some householders to admit the scavengers at short intervals, a *daily*

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[1] Under Sec. 89 of the Public Health (London) Act, 189 .

[2] "The Disposal of Town's Refuse (Boulnois).

system of collection should be adopted in all "built-up" areas. The plan of placing out the dust, in proper *covered* sanitary pails, either in the forecourt of the premises or on the street curb, is a good one, and effects considerable saving of time upon the rounds of the dustmen. For the sake of uniformity, and to prevent all sorts of unsuitable receptacles being used for this purpose, the portable dust pails should be supplied by the Sanitary Authority in districts where these objections would be of sufficient importance to warrant their so doing.

It would, of course, be impossible to lay down any one system of collection which would be applicable to all districts, as experience alone can prove what is the best plan to adopt in any particular case, but generally speaking the following methods, or some modification of them, are universally employed:—

(1) *The Portable Pail System of Collection.*—By this method the refuse is placed in small portable pails and placed to the front of the premises for the removal of the scavengers as they pass through the streets on their rounds at certain fixed intervals. The following is a brief description of the system as carried out in *Leyton*, a large urban area of some 90,000 inhabitants, and containing about 16,000 houses. With a view to the adoption of the system special by-laws were framed by the Council and approved by the Local Government Board devolving certain obligations upon householders in order to facilitate the work of collection. These by-laws, so far as is material, require that "the occupier of any premises on which any house refuse may from time to time accumulate shall, on such days and on such hour of the day as the Sanitary Authority shall fix and shall notify by public announcement in the district, *deposit on the curb-stone*, or on the outer edge of the footpath, immediately in front of such premises, or in a conveniently accessible position on the premises, as the Sanitary Authority may prescribe by written notice served upon the occupier, a *movable receptacle*, in which shall be placed, for the purpose of removal by or on behalf of the Sanitary Authority, the house refuse which has accumulated on such premises since the preceding collection by or on behalf of the Sanitary Authority."

At the introduction of the system notices were served upon the householders, pointing out the said obligations, and specifying the days upon which the scavengers would pass through the various streets. The duty of the men in performing their rounds simply consists in emptying into their carts the contents of the portable receptacles which they find placed out for their removal. They are particularly instructed not to enter in any case to the rear of premises in search of dust, and should such not be found ready for their removal they usually signify their presence by calling out, in a voice of a more or less stentorian character, the word "Dustman!" and shortly thereupon pass on. After a short period of working it was found that, when the men were familiar with their rounds, householders were able to tell approximately the *hour* of the day at which the dustcart would reach their premises, so that the usual objections raised to this system, of having pails standing in the forecourts or on the street curbs for the greater part of the day, with the result of having the refuse scattered about the streets, is not perceptible in this district; and when the work is well *organised* and *supervised*, plus a little co-operation on the part of householders, this objection vanishes altogether.

The entire district is divided into convenient divisions and workable sub-divisions for the purposes of collection, and the dust is collected from every house *twice in each week*, by eight horses and carts,[1] which are hired by the day—the Council employing four "fillers" to assist in the collection—and an additional horse and cart is engaged to collect from large institutions, such as the West Ham Union, Bethnal Green Schools, &c. The entire cost of the collection and disposal of the house refuse—to a "shoot" provided by the contractor—for the year ending March, 1896, was £1399 10s. 6d., which is equivalent to a cost of about 1s. 8d. per house per annum, or 3·7d. per head of the population per annum; whilst, when the collection was performed upon the old house-to-house call and fixed ashbin system, the total cost for the year ending March, 1894, was £1912,[2] being equal to about 2s. 9d. per house[3] per annum, or 5·7d. per head.

Upon the new system of collection it is found that considerable economy of time is effected in the dustmen being relieved of the duty of entering to the rear of premises for the purpose of clearing out large and over-laden ashpits, filled, oftentimes, with large quantities of garden and other organic refuse which, strictly speaking, ought not to be removed at public expense, and which may be easily disposed of in well-managed households upon the premises themselves. Also there is not the same temptation to the scavengers to waste time in sorting out the refuse, in conversing with servants and others, and in lingering about in the hope of receipt of gratuities in any form. In addition, the total amount of refuse collected from the district is considerably less than upon the fixed ashpit system, so that there is a further saving in cartage and also in the cost of ultimate disposal—the latter being of considerable importance where the refuse has to be deposited at expensive "shoots," barged away, or destroyed by fire.

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[1] The capacity of the carts is 3 cubic yards.

[2] Notwithstanding the fact that the population in 1894 was much less than in 1896.

[3] The average cost per house per annum in the metropolis for the removal of house refuse is a little over 4s. In the Hornsey district the average cost per house per annum for the five years 1879 to 1884 was 11·02d., the D system of calling and fixed ashbins, of capacity restricted to 6 cubic feet, being the methods in vogue.

(2) *The "Bell Cart" System.*—In this the carts pass through the streets, and a bell attached to the horses warns the householders to bring out their refuse. The objections to the system are that the *bell* adds its quota to the already excessive tumult of unseemly "street noises;" that the refuse is oftentimes brought out by the occupiers long before the probable approach of the dust cart, and in most inappropriate receptacles, which unfortunately at times attract the attention, amongst others, of mischievous boys, hungry dogs, and inquisitive rag-pickers.

(3) *The D Cart System* consists in the occupier placing a card bearing the letter D in large type in the window, when a call from the scavenger is required. These cards are usually printed and circulated by the Local Authority, and should state on the back the day and *hour*—as approximate as possible—at which the dust-cart will appear. Every effort should be made to adhere as strictly as possible to the times stated, so that the work of collection may be facilitated, and the householders not unnecessarily inconvenienced. The use of this card effects a saving of time on the rounds by enabling the men to avoid making needless calls.

(4) *Calling upon receipt of Notice* from the occupier is sometimes the plan adopted, but this practice is at once condemned upon sanitary grounds, as "it tends to large storage of decomposing refuse, and depends upon the vigilance or neglect of the occupier of the premises."

(5) *Periodical Collection* from house to house at *fixed* intervals without waiting for notice from the occupier. The collections are usually either daily, thrice, twice, or once weekly, or in some cases even less.

(6) *Collection from Public Dust-bins* fixed by the Local Authority in suitable positions in order that householders in their immediate locality can place their refuse into them. Their clearance being effected by the Authority as necessary. This system is a very useful one in the poorer and more densely-populated districts of a town, and, were it not for the objections which are raised sometimes by the occupiers of adjacent houses as above mentioned.

"If these dust-bins were constructed with properly balanced self-closing lids, these objections might be overcome, and their first cost would be but trifling when compared with the benefit to be derived by placing them in some of the thickly-populated courts and alleys which are unfortunately to be found in nearly every town. Where there are no public dust-bins, the inhabitants of these courts throw their waste products upon the surface of the streets or courts, from time to time throughout the day, as it cannot be expected nor desired that such materials should remain, even for twenty-four hours, in their one living room, which is frequently overcrowded and has but little spare space even for the common necessities of life; but that these waste products should be thus strewn over the surface of the street or court is almost equally objectionable, and points to the advantage to be gained by placing in convenient situations covered dust-bins which could be easily *emptied once a day*."

The following description of the collection of house refuse in Kensington, given by Mr. William Weaver, M. Inst. C.E., surveyor to the Vestry, in a paper[1] read before the Association of Municipal and County Engineers in 1892, on the public works of that district, will be of interest:—

"The dust is collected regularly on stated days from each house in the parish; no house is visited less frequently than *once a week;* from some premises the refuse is removed *twice*, and others *thrice* a week, and in some cases (residential flats) the carts call *daily*. The Vestry would seriously entertain the question of a *daily removal* throughout the parish, were they armed with power to compel the abolition of dust-bins or dust-holes, and to enforce in lieu thereof the provision of movable receptacles. Having failed in their endeavours to get the late Metropolitan Board to apply for such powers, and the New Public Health (London) Act, moreover, sanctioning the continuance of the old insanitary type, the Vestry and its officers consider that it is not advisable to embark upon such work of daily collection. Doubtless, the great majority of householders could be induced to use, and at stated times put out movable receptacles, but the non-agreement of a small minority would be quite sufficient to put the whole work out of gear.

"The collected house refuse, amounting to about 45,000 loads per annum (a load averages 23 cwt.), is barged away on the river Thames to the south of the parish, and the Grand Junction Canal in the north district. For each load shot into barge on river, the Vestry pays 1s. 11d. per *load*, and on canal 2s. 4d. per *ton*. Some 24,000 loads have been delivered to the *Refuse Disposal Company* at Chelsea, the Vestry paying 1s. 9d. per load.

"The Vestry is of opinion that the house and street refuse can be utilised for agricultural and brick-making purposes, and towards this end 18 acres of land have been purchased at Purfleet, abutting on river and rail, and experiments are now (March, 1892) being made with the refuse deposited on the land. A committee of the Vestry is now seeking for suitable similar land on the banks of the canal.

"It will be seen that the collection and disposal of the house and street refuse of Kensington entails a very large expenditure. Doubtless the work could be done much cheaper. *Fire* would destroy the house refuse at a cost of about 1s. a ton, with a residue of about one-sixth to barge away, instead of the whole being barged away as at present at a cost of about 2s. a ton; but it must be borne in mind that in a district like Kensington the *cost* of the work *itself* is not the only item to be considered, the effect on the district must be taken into account.

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[1] "Proceedings" of the Association of Municipal and County Engineers, vol. xviii.

"The author's reports to the Vestry were in favour of the erection of a destructor for consuming the non-saleable part of the house refuse, and the employment of the waste heat in working machinery, first, for the washing of the refuse from flint and macadam roads, and secondly for the generation of electricity."

Dust and Scavenging Carts.—The ordinary "tip cart" is that in general use. It consists of an oak frame, and elm or deal sides, holds from 2 to 4 cubic yards, and costs from £18 to £20. These carts are heavy, somewhat clumsy, and are usually mounted by the scavenger, plus a ladder.

Many improved carts and wagons have been introduced, and are variously styled by the makers, such as "dust carts," "sanitary carts," "slush carts," "general purpose carts," "tumbler carts," "slop wagons," "mud wagons," &c. They are built low upon their axles, and consist of iron bodies upon wooden frames and wheels. Sometimes they are entirely covered by means of a movable lid, or are simply supplied with hinged sideboards inclining inwards, in order to prevent the contents from splashing. There is also provision for tipping by some special means, such as a chain and windlass. A good cart should be as light as possible, combined with strength and durability, should bear with a minimum of weight upon the horse, should admit of easy cleansing and disinfection, and be as economical in both first cost and maintenance as possible.

In organising a proper system of house-refuse collection, the following points must be kept in view as being essential to success:—

(1) The collections must be *frequent*, so as to admit only of *small* accumulations of refuse, thus producing a maximum of benefit to the public health.

(2) A thoroughly *systematic and regular daily routine* must be adhered to, so that householders may know as precisely as possible when the scavengers will appear, thereby giving rise to the minimum inconvenience to the public, and inducing their fuller co-operation, which will considerably facilitate the work of collection.

(3) There must be an official, such as the Sanitary Inspector or a Dust Inspector, whose duty it is to make house-to-house visits to see that all refuse is properly removed from the premises within the district.

(4) Householders should be well informed as to what *is* house

refuse, and as much garden, vegetable, and other organic matter as possible, should be consumed or buried upon the premises.

(5) There should be a proper method and recognised charge per load for the removal of "*trade refuse.*"

(6) The system adopted should be that which is found to be the most *economical* combined with *efficiency*.

CHAPTER III.

THE REMOVAL OF EXCRETA.

This work is carried out on one of two systems, viz., either upon the
(*a*) Conservancy system, or upon the
(*b*) Water-carriage system.

Notwithstanding the manifest inadequacy of all "conservancy" methods of performing this work, the system dies a very slow death in some parts of the country, and probably in sparsely-populated rural districts it will never become wholly extinct.

The North of England generally is much behind the times in regard to this important question of the satisfactory removal of excreta from amongst its centres of population; many, even large towns, being still served by one form or other of those cumbersome and dirty methods the technical nomenclature of which is embodied in some half-a-dozen more or less odoriferous terms, such as midden cesspool, pail, tub, poudrette, and so forth. As the time when the whole of these abominations will have entirely disappeared from amongst thickly-populated towns and will be remembered only as curious bits of ancient history is a most agreeable mental projection to indulge in and a still more desirable end to be attained, it will be unnecessary to do more than give a brief outline of this process of collection.

The difficulties of sewage disposal, including the probable penalties of river pollution, together with an inherent reluctance to the spending of large sums of money in sewerage operations and in the provision of an improved water supply necessitated by the adoption of "water carriage," have no doubt been the means of inducing many Local Authorities to postpone the installation of a proper system of arterial drainage.

***The "Conservancy System"* may be defined as the name given to the practice of retaining and collecting excreta and waste substances with a view of turning them to account as manure.**

In practice the system is known in the following forms:—The midden, the cesspool, the pail or tub, and the dry-earth system.

***The Midden System.*—The old-fashioned privy, with its capacious and typically insanitary pit or midden, was the earliest form of the conservancy methods practised. The *midden* consists merely of a hole in the ground, sometimes lined with rough masonry or jointless brickwork, made for the reception of excreta, ashes, slop water, and**

garbage. Its capacity is generally considerable, and being usually as porous as it is possible to construct it, the processes of emptying are spread over wide intervals of from six to twelve months or more. Dr. Buchanan, in a report of his, written in 1869, describes the middens of Birmingham in the following terms:—"At present it is common to find huge, wet, fœtid middens, uncovered, undrained, unemptied, some of them as deep and big as the foundations of an ordinary cottage. Few of them are covered, the Inspector of Nuisances thinking they are better left open. Many are under workshops, where work is done amid stench all the year round, and among swarms of flies in the summer."

Cesspools.—These were built usually of dry masonry or brickwork, sometimes in the basements of large houses in towns, or in the gardens of suburban and country houses, and are designed for the reception of the drainage from water-closets, including the usual slop and waste waters of households. They were usually arched over, or covered with a flat stone, and provided with an overflow into the nearest pond or stream. A prominent object in their construction, as in the case of the midden, was to make them as large and porous as conveniently possible, so that, when provided also with ample overflow, their cleansing would be an undertaking of the rarest possible occurrence—a principle quite contrary to all modern notions of sanitation. At one time it was considered undesirable to admit the discharges from w.c.'s direct into sewers where such were provided, and the cesspool was oftentimes introduced to intercept the solids, and to act as a kind of settling chamber, an overflow from which was connected to the sewer. As a natural consequence of this, as long as the overflow "worked" there was no apparent reason for cleansing these cesspits, and they were allowed to remain, numbers of them being therefore entirely forgotten, and thus remained as "the embodiment of all that was vile and unhealthy." "Only within the last twelve months one of them was discovered in Buckingham-street, Strand; in this case the house drains had been disconnected so that no direct communication existed, the cesspit was directly in the line with a new sewer, and the stench liberated by the excavator can be better imagined than described,"[1] or at any rate preferably imagined than experienced.

The evils of the privy, cesspool, and midden systems are too obvious to need further comment, except to say that in all cases they should be promptly abolished. Cases have been met with where people were living in houses with walls saturated with privy filth, and the rooms stinking with privy effluvia; the unfortunate inmates suffering from nausea, sore throats, and the like. The soakage from cesspools, middens, &c., entering wells and other sources of water supply has been a very fruitful source of typhoid fever.

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[1] *Journal of Sanitary Institute*, vol. xvi., p. 474.

The cesspool is not prohibited either by the Public Health Act, 1875, or by the Public Health (London) Act, 1891, but the Model By-laws of the Local Government Board, where adopted, will ensure its more sanitary construction. These regulations require that it shall be constructed only at an adequate distance from dwelling-houses,[1] or from sources of water supply,[2] such as wells, springs, &c.; that its position and construction shall afford reasonable facilities for effectual cleansing, and that there shall be no communication to any sewer. The cesspool is also to be built of good brickwork in cement, with a backing of 9in.[3] of well-puddled clay, to be rendered inside with cement, to be arched over, or otherwise properly covered, and to be ventilated.

The emptying of cesspools is performed in the most inoffensive manner upon the pneumatic system, as follows:—

A large air-tight cylinder or a number of air-tight barrels connected by 8in. tubes, and mounted on wheels, is brought to the cesspit, and to which the cylinder is connected by a tube of 8in. diameter from a stop-cock on one of the barrels or cylinders. A vacuum is then formed in the cylinder by means of an air pump, or injected steam, and upon the stop-cock being opened the contents of the cesspool are forced through the tube into the cylinder by the atmospheric pressure.

The principle of this method is similar to what is known as *Liernur's System* of clearing closets by connecting same by iron pipes with an air-tight central tank into which the excreta is drawn by exhausting the air from it at intervals.

Combined Privy and Ashpit. — This combination was the next advance, and was a decided improvement upon the old midden. Although far from satisfactory, this system is still in use in many country districts. The diagram, Fig. 1, illustrates the arrangement of the Nottingham ashpit. The pit, which is about 80 cubic feet capacity, is built with a curved bottom and rendered in cement. It forms the common receptacle for the excreta from a privy on either side; also for ashes and garbage through a door, provided as shown. Institutions of this style were designed with a view of clearance about once in three months.

Further improvements still took the form of greatly reducing the size of the pit, or "fixed receptacle," as it is called in the Local Government Board Model By-laws, and the perfect privy therein portrayed has a capacity of about 8 cubic feet, is constructed of *impervious* materials, excludes all rainfall or other moisture, and is fitted with suitable apparatus[1] for the frequent and effectual applica-

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[1] Say, 50ft. distant at least.

[2] Say, 80ft. distant at least.

[3] More or less, as considered necessary.

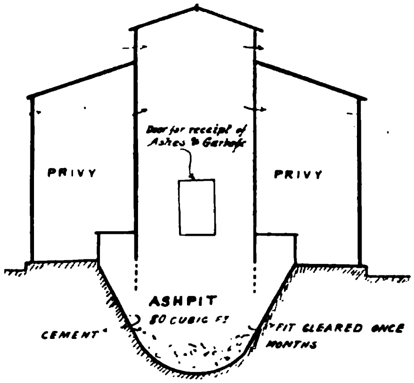
Door for receipt of Ashes & Garbage
PRIVY
PRIVY
ASHPIT
80 CUBIC FT
CEMENT
PIT CLEARED ONCE IN 3 MONTHS

Fig. 1.

THE NOTTINGHAM ASHPIT PRIVY.

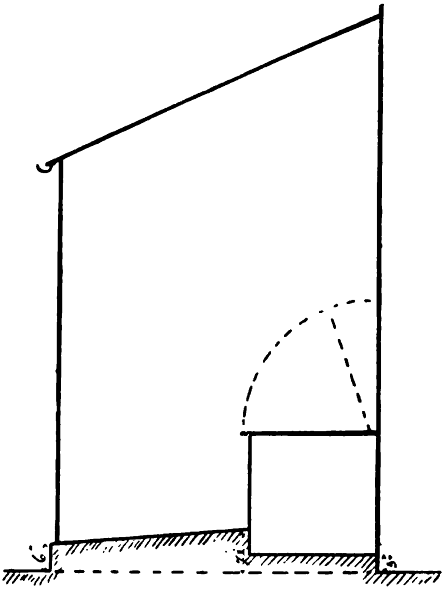

Fig. 2.

IMPROVED PRIVY WITH SMALL "FIXED RECEPTACLE."

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[1] *Morrell's cinder-sifter* is an apparatus automatically answering this purpose, by means of the weight of the user upon the seat.

tion of ashes, dust, or *dry* refuse to the filth that may be deposited therein. This privy is intended for a *weekly* scavenging.

The Pail System. — This is a considerable advance upon the methods previously described, and its introduction has been very successful in small and scattered districts, although not applicable to large centres of population. Instead of the excreta being directly deposited into the chamber represented in Fig. 2, a small movable pail, of about 2 cubic feet capacity,[1] is placed therein, and thus greatly facilitates the speedy removal of the filth, the scavengers simply removing the full pail and replacing it by a clean one.

The "tub and pail" system was first adopted in its entirety at Rochdale, where it has been carried out successfully, so far as the nature of the work will admit,[2] since the time of its introduction in 1869. There are now about twenty-four towns in England which have extensively adopted this system, but the following description of the Rochdale arrangements may be taken as typical of the system generally:—

"*The Rochdale System* has for its object the collection, at weekly or shorter intervals, of the excrement and dry refuse from households in two separate pails; the manufacture of the excrement into manure, and a thorough utilisation of all the collected refuse. This work is done so as not to create any nuisance, and without trouble to, or assistance from, the householders, and is carried out as a part of the work of the Sanitary Authority.

"For the purpose of collecting, the town is divided into districts; the closets in each district have a letter and a consecutive number on the door. The number of each pail and ash-tub are also entered in a book appropriated to each letter. On leaving the works the guard of each van is supplied with the names of the streets and twenty-four closets in each, from which he is to collect the pails, and to fill in the letter and number of the closets on his blank list with which he is furnished. On returning to the works the van is weighed and the list given to the clerk. An Inspector daily enters from these lists into the division books the number of the pails brought in, and by this means, at the end of every week, it can readily be seen what pails, if any, have been omitted. When this happens a special van is sent out to make good this defect. It is also the duty of this Inspector to visit the different closets in his district to see that the pails returned as changed have been done; and thus a wholesome and necessary check is applied to the collector's returns. Before being sent out every pail has been thoroughly washed by means of a hose delivering water under a strong pressure, and into each pail is added about half a pint of disinfecting fluid. The guard of the ash cart is furnished with a list having only the name of some street or streets he is ordered to visit—the far end of this given district—and to empty sufficient ash-tubs as will make a cart load, at the same time entering the number of each closet on his list. This list is also handed to the weigh clerk when the cart is weighed, and posted by the Inspector in the division or letter book. The excreta pails in use are made from the half of a mineral oil cask. Each pail, on its removal from the closet, is supplied with a lid, which has a circular ring of india-rubber, upon which presses the upper part of the pail when the lid is fastened down by a spring which is connected to the pail by two links. This lid has proved a simple but effectual means against any nuisance from the pails while they are being carted to the works."[1]

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[1] *The Rochdale pails*, made from petroleum casks cut in halves, re-stained and hooped, when finished measure 18in. in diameter at the top, 15in. at bottom, and about 16in. deep.

[2] Sir Robert Rawlinson has described the "tub or pail system" as a "filthy, stinking abomination."

The contents of the pails used for excreta are treated as follows:—

"The pails are on removal from the vans emptied into tanks; the excreta in the tanks being mixed with sulphuric acid in the proportion of 24 lbs. of acid to the ton (to fix the ammonia).

"It is then run into revolving cylinders, about 6ft. diameter, through which all the smoke and hot air from specially constructed furnaces pass. The revolutions of the cylinders agitate the excreta, thus exposing fresh surfaces to the hot air.

"The charge of a cylinder is 3½ tons, which in twelve hours is reduced to nearly 5¼ cwt. of a material very like hard clay, which is dried on hot plates. The manure, when dried to 10 per cent. or 12 per cent. of moisture, is ground in a pug mill and sold in sacks at about £6 per ton as a valuable manure."[2]

To meet the objections of so much liquid being deposited in the pail, and to endeavour to deodorise the contents, modifications of the Rochdale plan have been adopted, known as the "*Manchester System*," where the fire ash is thrown off a riddle into the pail containing the excreta.

That known as the "*Goux*" *System*, and extensively carried out at Halifax, seeks the same object by lining the pail with waste material from woollen and cotton mills, chopped straw, sweepings, &c.

The pail system, in the absence of a proper system of arterial main drainage, is suitable for large isolated institutions where every attention can be given, and also for small rural districts, but certainly not for large towns.

Cost of Collecting Excreta and Ashes under the Pail System.—As to the cost of this work, Mr. George J. C. Broom, M. Inst. C.E.,

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[1] "The Rochdale System," p. 6.

[2] *The Journal of the Sanitary Institute*, vol. xvi., page 475.

Borough Engineer of *St. Helens*, Lancashire, where the expenditure on the work has been very carefully recorded, states that "it is found to be equal to an average of 2·183d. *per pail per week* for the ten years the system has been working; this cost includes the collecting of pails and ashes and carting same to depôt, and to this amount must be added the wages of men changing and washing pails, which is equal to ·185d., making a total of 2·368d. per pail per week. An additional expense is, however, in many cases incurred as a result of some pails requiring to be emptied twice, or perhaps three times, per week; and as these pails are generally distributed over a large area this is a serious item, and increases considerably the average cost per pail.

The actual cost necessarily varies with the local circumstances of each town, such as distance from depôt, &c.; but an average cost of 12s. per pail per annum is given[1] as adequate for daily removal and cleansing of pails sufficient to prevent nuisance.

The Advantages and Disadvantages of the pail system have thus been summarised by Mr. Broom, St. Helens:—

Advantages.—(*a*) The system has been beneficial as an intermediate between the midden and water-carriage, thus affording Local Authorities more time for the fuller consideration of questions of sewerage.

(*b*) It is an immense stride in advance of the midden system, the excreta being removed more easily, frequently, and without much nuisance.

(*c*) It may be of service in towns where an adequate water supply cannot be obtained readily, or without excessive expenditure.

(*d*) It is adapted to the requirements of sparsely-populated districts and villages whose water supply is from wells, and where the excreta would be utilised on the spot as a manure.

Disadvantages.—(*a*) The system is not suited to large towns, owing to the great cost in carriage on pails, and in dealing with the excreta.

(*b*) It cannot well be carried out without nuisance to the inhabitants.

(*c*) Being a "conservancy system," it is not the best mode of dealing with the excreta, independent of the question of cost.

(*d*) In the event of its introduction, nothing is ultimately saved in the construction of a system of sewerage, and very little annual cost in the carrying on of outfall works.

The system, it may be added, is now dying out, and those towns which have adopted it are turning their attention to the problem of an efficient scheme of "water carriage," which is undoubtedly the best and cheapest method known.

A Natural Method of Excreta Disposal.—A very primitive, natural, and, where there is land available, good method of disposal of pail excreta is that carried on in America on the banks of Hemlock Lake —the water from which is used for drinking purposes for the city of Rochester. There would, however, appear to be serious risk in carrying out this mode of disposal so near to a source of water supply, bearing in mind the recent outbreaks of typhoid at Maidstone and Lynn, and similar catastrophes. The following is the process adopted:—

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[1] "Proceedings" Assoc. Municipal and County Engineers, vol. x., page 47.

"The pails and garbage are collected and removed to the foot of the lake in a flat-bottom steamboat; it is then transported by a tramway 1800ft. long to the disposal ground, where the refuse is treated as follows: Narrow trenches are excavated 3ft. apart and 3ft. deep, care being taken that the permanent level of the subsoil water is not reached; the contents of the pails are deposited therein in thin layers, and immediately covered with dry loam to a depth of 6in. After each trench is filled it is rounded up with earth, the location of the trench recorded, the surface being cultivated and cropped."[1] From examinations of the soil of these trenches, with a view of ascertaining whether complete decomposition had taken place, it appeared that shallow trenches were better suited to the purpose than deep ones, and that after a period of three years the indication is that the same trench may be used again.

The Dry-earth System.—In practice this system is found to be most successful in such public institutions as workhouses, jails, schools, and railway stations, or in connection with large country houses. The success of its working depends upon someone being made responsible for the necessary supply of dry earth (loamy earth and clay are best) and the *systematic* removal of the pails.

An important feature of the system is the addition of a given quantity of dried earth, about 1½ lb. to the contents of the pail or tub each time it is used. The mixture resulting has little or no odour, and, after being stored for a time in the open air, can be again used as a deodoriser in the closet.

Moule's earth-closet provides a mechanical contrivance whereby a regulated weight of earth is automatically thrown into the closet.

Dr. G. V. Poore has also designed a simple pan for use in dry closets, which are provided with an ample receptacle or "dry catch" beneath. The lower end of this pan passes through the floor and projects into a "dry catch" below. A flap, which acts automatically by means of a counterpoise, is fixed at the bottom of the pan, and allows the dejecta to drop out of sight and prevents updraught. The apparatus is especially applicable for dry closets which are approached from the bedroom floor of a house.[1] Speaking of the dry-earth system generally, "if, in a properly-constructed closet (such as that anticipated in the Model By-laws, Clause 71, which relates to 'earth-closets with fixed receptacles') dry earth in suitable quantities is applied to the excreta with regularity and frequency, no sanitary disadvantage will be found to result if the contents are allowed to remain undisturbed for a period of, say, three months. Indeed, the process of disintegration and of combination between the earth and the organic matter is, after due lapse of time, so complete that the stools and even the paper entirely disappear among the other constituents of the compost. The absence of fætor from the mixture, even with prolonged keeping, shows that decomposition in the ordinary sense does not take place.[2] And hence, where other closets than *water-closets* are in use it is desirable to favour the construction of *earth-closets* rather than *privies*, by sanctioning a removal of contents at comparatively long intervals. This is especially desirable in districts where such soils as clay, loamy surface earth, and brick earth of the drift, are easily procured, because such soils when dried are specially adapted to the purposes of dry-earth closets. On the other hand, chalk has very little, and sand and gravel still less, value for such a purpose.[3]

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[1] *The Journal of the Sanitary Institute*, vol. xv., page 668.

Under the Model By-laws[4] an *earth-closet* may be constructed inside a "building," but when so placed a "*movable* receptacle" of a maximum capacity of two cubic feet should be required.

Dr. Poore, in an interesting paper on the "Dry Methods of Sanitation," delivered at the Sanitary Institute,[5] observes that "the change which is produced in excrement when mixed with earth whereby the excrement is humified, *i.e.*, changed to something which is indistinguishable by our senses from ordinary garden mould, or humus, is due to the action of fungoid organisms. . . . A very important organism or class of organisms in this connection are those which bring about the nitrification of nitrogenous matters, whereby they are oxidised and made soluble, so as to be readily absorbed by the roots of growing plants. . . . It is not likely that nitrification is the sole change which takes place; and it is at least highly probable that many of the fungi which grow in nitrogenous matter play a very important part in producing fertility and in feeding higher plants. The intestines of animals swarm with bacteria and allied bodies; and it may be assumed, in the absence of evidence to the contrary, that excrements carry with them, so to say, in the form of bacilli and bacteria, bodies which help in their subsequent humification. . . . Ordinary humus contains such organisms in countless numbers; but it is probable that when excreta are mixed with sterile bodies, such as ashes, the necessary organisms are in part supplied by the excreta themselves, or possibly gain access from the air around.

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[1] See *Journal of Sanitary Institute*, vol. xvi., page 283.

[2] "The Twelfth Report of the Medical Officer of the Privy Council, 1869."

[3] See "Knight's Annotated Model By-laws."

[4] Clause 67, By-laws with respect to "New Streets and Buildings."

[5] February 13th, 1895.

"In order that humification may take place two things are necessary—

"(1) The matter must be *tolerably dry*. Absolute dryness checks the process; so does excess of moisture. It is stated that about 33 per cent. of moisture is the amount with which the humifying change is most rapid.

"(2) The *access of air* is necessary because the organisms which produce humification are aërobic, and, as much of the change consists of oxidation, it is evident that the free access of air is essential."

Continental Systems.—There are three systems in use on the Continent, which appear to take an intermediate position between the dry methods and water-carriage, which may be briefly mentioned:—

The Fosse Mobile is a covered movable tub situated outside the house, and into which the closets discharge through a fixed pipe. When full, the tub is simply replaced by an empty one.

The Fosse Permanente.—This is a large air-tight underground tank connected by pipes with the closets, and emptied pneumatically at considerable intervals into an air-tight cart.

The Liernur System, already referred to above in connection with the emptying of cesspools, was introduced by Captain Liernur, a Dutch engineer, and is in operation in St. Petersburg, Amsterdam, Prague, and other continental towns. A town is divided into districts, and the water-closets are connected by means of air-tight pipes with a central air-tight iron tank which itself communicates with air pumps and collecting reservoirs at a central station for the purpose of removing excreta, &c., upon the pneumatic system. The working expenses of this method are given at about 4s. 10d. per head per annum.

Shone's Pneumatic Ejector System.—This method has for its object the interception and lifting of sewage at various points throughout low-lying districts, in order to avoid deep cuttings for sewers, excessive pumping "lifts" at the central station, and to secure good self-cleansing gradients in sewers in flat districts. The "ejectors" are placed at various suitable points in the drainage area, their duty being to lift the sewage passing through them from a low to a higher level by means of compressed air supplied through cast iron mains from one central station.

The system has been extensively carried out, amongst many other places, at Wallingford and Rangoon; the cost per head for installation at the former town was £8 9s.

"The ejectors are cast iron receivers of a suitable form, placed underground at depths to suit the locality, into which ejectors the sewage flows through the ordinary pipe drains from the houses. As the liquid rises in the interior of the ejector, and when full, it lifts a valve and admits compressed air from an engine which supplies the entire district. The ejectors are thus emptied of their contents, which are blown out in about eighty seconds of time, and the sewage passes through cast iron main pipes of suitable diameters to the land, or other outlet provided to receive it, or it may be distributed upon the waste land as it passes through."

Slop-water Closets.—These have been introduced for the purpose of utilising house waste water in the flushing of closets, with the object of avoiding the expense of a separate water supply. There are several forms of this type of closet, viz., Fowler's, Duckett's, and the Crewe slop-water closet; that illustrated in the accompanying Fig. 8 being Duckett's patent automatic apparatus. A "feed pipe" conveys the household waste water into a "revolver" or "tipper," which is a stoneware vessel working on pivots, and so fixed as to discharge by overbalancing when full, sending its contents, about three gallons, forcibly into the trap as shown in the figure, and then swinging back into its original position. The illustration given will render any description of the constructional details of the apparatus unnecessary.

A good form of ordinary water-closet, properly fitted up and flushed with *clean water*, is very much to be preferred, and more sanitary, as the flushing with *slop water* is not likely to keep the interior surfaces free from offensive accumulations. These closets now, however, are brought to a considerable degree of perfection, and in the North of England are extensively replacing the "pail closet." The cost of the apparatus, as manufactured by Messrs. J. Duckett and Son, Limited, is about £2 10s. fixed complete, and the cost of converting from "pail closet" to slop-water closet, under ordinary circumstances, is about £3, including drainage alterations. In Accrington it is stated that each waste-water closet introduced effected a saving of 6s. per annum in scavenging, as compared with the annual cost of the pail closet system. In Burnley, where there are some 18,000 slop-water closets now in use, the saving thus produced is given at 2s. 6d. per annum per closet converted. The consumption of water per head of the population, where these closets are used, has been found to be about the same as where a conservancy system exists.

The Water-carriage System: *Sewerage.*—Under this method all solid excretal refuse and foul waste water is promptly washed away from the premises upon which it is created, and immediately passes away through stoneware pipe drains, usually of about 6in. diameter, into large main sewers laid at considerable depths in the public streets.

Works of "sewerage," or the construction of main sewers, are carried out either upon what is called the "*separate*" system or the "*combined*" system.

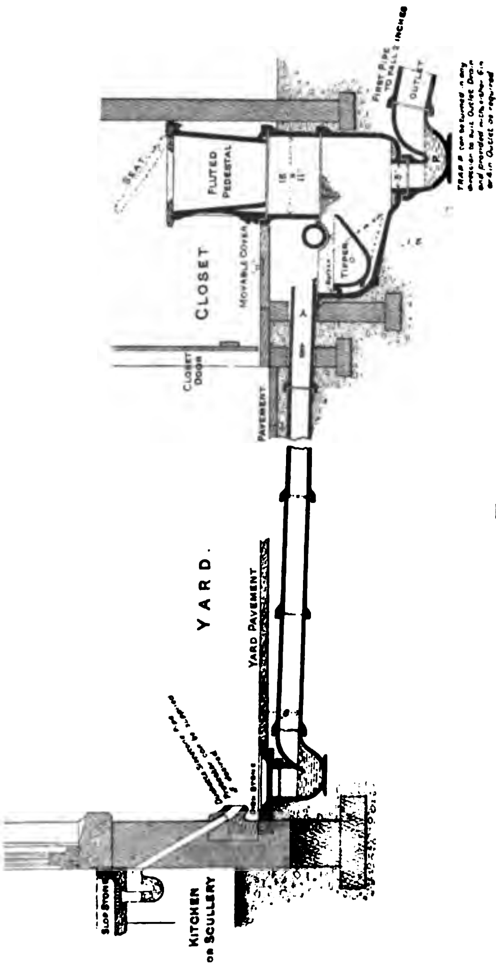
CLOSET
CLOSET DOOR
MOVABLE COVER
FLUTED PEDESTAL
SEAT
FIRST PIPE TO FALL 2 INCHES
OUTLET
TIPPER
A
B
P
PAVEMENT
TRAP P can be turned in any direction to suit Outlet Drain and provided with either 6in or 4in Outlet as required
YARD.
YARD PAVEMENT
KITCHEN OR SCULLERY
SLOP STONE

FIG. 8.
DUCKETT'S PATENT AUTOMATIC SLOP-WATER CLOSET APPARATUS.

In the "*separate system*" a large proportion of the rainfall is conveyed away in a distinct system of surface-water sewers, which usually have their outfalls in any convenient natural watercourse. For practical reasons it is not often attempted to conduct *the whole* of the rainfall into surface-water sewers, but principally that only which falls upon street surfaces and the fronts of houses. The rain water falling upon backyards and the rear of buildings is usually admitted to the sewage sewers in order to avoid a duplicate system of house drainage, which would lead to hopeless complications and much needless expense.

The "*combined system*" is that in which one set of sewers receive the whole of the drainage of the district, including sewage, surface-water, and all other drainage.

The respective merits or otherwise of these two systems, and the many details of their construction, are matters which properly come under the head of "Sewerage" or "Main Drainage," and do not therefore fall within the scope of the present work. It may, however, be briefly stated that for an efficient system of main drainage it is essential that all sewers be thoroughly well constructed, with good gradients, and of the best materials; also that they be well ventilated and systematically flushed, and that the sewage at the outfall be disposed of in the best possible manner.

Selection of a System.—Although the question of the best mode of removing excreta has formerly given rise to a good deal of controversy, it cannot be considered a very difficult one at the present day. It is well known that no large centres of population can exist without adequate provision of sewers to carry off the foul waste household water, urine, &c., and the question of the choice of a system is therefore reduced to simply whether or not fæcal excreta should be admitted into the sewers.

Water-carriage is now, without exception, regarded as the *best*, and in fact the only, system that can be adopted for large (or even moderate sized) towns, ensuring, as it does, greater health, cleanliness, and convenience to the inhabitants accommodated. This system has extended very largely during recent years, and in nearly all towns where dry methods are in use their entire abandonment is either in contemplation or in progress in favour of the installation of a proper system of "sewerage."

Speaking generally of "conservancy systems," they are cumbersome, expensive, and uncleanly. There is a tendency in all such methods to keep refuse matters on the premises a long time; whilst, so far as public health is concerned, *riddance* of all refuse matters is much more important than their collection and utilisation. The system is therefore based upon an entirely wrong principle. Sewers have still to be provided for the removal of foul waste water, whilst in the water-carriage system both waste water and excrement are conveyed away by the sewers. It is, of course, no argument against water-carriage to say that sewers are badly constructed, and as a result give rise to certain serious evils, but it is naturally presupposed that they are laid with all the precision and skill of modern sanitary science. With "pails" there is always a certain amount of unavoidable offensiveness, however well managed; and the removal of the contents of the pails, and the ultimate disposal of the refuse, is a business of a most unostentatious character, and one involving considerable labour and expense. The regular provision of an adequate supply of dry earth for deodorising purposes is also a matter of some difficulty.

The "dry methods," however, still have a use, and are capable of doing good service in sparsely-populated and straggling country districts having a few houses scattered, as if promiscuously, here and there. The water-carriage system in such areas would be entirely out of the question, and its cost altogether disproportionate to the rateable value of the district. Here, the dry-earth closet with a small movable pail and the necessary facilities and appliances for the application of dry earth or ashes, is, when regularly and properly attended to, fully adequate for the requirements, and forms a perfectly sanitary institution. Also, the rural nature of the surroundings afford every facility for the ready disposal of the pail contents.

The old-fashioned privy, midden, and cesspool, however, are without a single redeeming feature to justify their existence, and, in country districts, where they are so common, the dry-closet should be installed in their stead.

CHAPTER IV.

DISPOSAL OF TOWN REFUSE.

Having now somewhat fully considered the *varieties of refuse* to be dealt with, the *composition*, *quantity*, &c., of same; also, the different means which have been adopted for the purposes of *temporary storage* upon premises, and the various *systems of collection* or removal from the dwellings where created—the remaining question, and one of considerable importance and difficulty, is that of the methods of "*disposal.*"

These methods, as may well be expected, vary widely in different parts of the country, according as they may be influenced by local circumstances; but it may be at once stated that, for all large towns, the destruction (and oftentimes even *utilisation*) of refuse by cremation is at the present day regarded as being at once the most sanitary, efficient, and in many cases the *only* means of satisfactory disposal.

In districts, however, of a semi-rural character, or wherever there is, within a fairly reasonable distance, suitable waste land available for the "shooting" or tipping of house refuse, this is, and will no doubt continue to be, the most general means of riddance of this material.

The most prominent and influential question occupying the minds of those having the control of these matters is, as a rule, not (as may be reasonably anticipated) *what is the most sanitary method of disposal?* but, what is, for the time being, the most economical?

This being so, the *Refuse Destructor* is naturally regarded as an altogether needless luxury *until* all neighbouring available waste lands, hollows, &c., have been entirely monopolised, probably not only by the town refuse but also by rows of streets and houses. This juncture in the town's history having been arrived at, when carting or barging to more distant "shoots" would be too expensive an operation to be entertained, attention is then turned toward the capabilities of the "*Destructor*" as the only possible outlet for the difficulty.

Before its ultimate adoption, however, the town surveyor will be called upon for sundry reports as to the various means of refuse disposal, showing from carefully-prepared figures, the comparative costs of disposal per ton of refuse under any of the systems which would be practicable in the town in question; and at this stage of municipal development the "Destructor" is generally found to be the most economical—hence its adoption.

The next step is the collection of the *latest* information upon Destructor furnaces by correspondence and visits, for the purposes of observation and experiment, to the best-known installations throughout the country.

The questions as to the *type* of furnace to be adopted, and as to whether any provision is to be made for the utilisation of heat generated by the burning of refuse having been determined, the usual specifications, plans, estimates, &c., are prepared, the sanction of the Local Government Board for the necessary loan obtained, the contract signed, and the Destructor may now be regarded as being safely on the road towards soon becoming an accomplished fact.

Before pursuing the subject of the destructor further, it will be well to consider in detail the various other methods of disposal which have been made use of according as local circumstances may have invited their adoption.

For convenience, the chief methods employed may be briefly summarised as follows:—

(*a*) The mixing of household ashes, dust, &c., with pail excreta for the purposes of their common disposal by sale or otherwise to farmers for agricultural purposes.

(*b*) Carting house refuse outside of town boundaries, and "shooting' same upon waste land to fill hollows, raise level of marsh land, &c.

(*c*) Selling or giving away to brickmakers.

(*d*) Mixing with lime and using as manure on fields.

(*e*) Mixing with sludge of sewage farms and ploughing or digging into soil of farm.

(*f*) Mixing with precipitated liquid sewage sludge, and cremating in destructor furnaces, as at Ealing.

(*g*) Mixing with pressed sewage-sludge cake, and cremating in destructor furnaces, as at Leyton.

(*h*) Riddling, burning cinders and vegetable refuse to generate steam, and using fine dust in connection with a manure manufactory (tub system) the old iron being sold, and the pots, &c., used for the foundations of roads.

(*i*) Selling by tender yearly.

(*j*) Barging away down canals to country districts.

(*k*) Taking out to sea in hopper barges and sinking refuse in deep water, as at Liverpool.

(*l*) Utilising by "sorting" and selling ingredients, as done at Chelsea, by the Refuse Disposal Company, and at other dust contractor's yards.

(*m*) Destroying (without mixture, as in cases *f* and *g*) by fire in patent destructor furnaces.

Tipping on Waste Land.—As has already been pointed out, the practice of carting house refuse to the nearest available waste land and tipping it there, or filling up disused brick yards in close proximity to towns, is, where its adoption is practicable, the most favoured method of disposal. The system, however, to say the least of it, is a somewhat rough-and-ready way of getting rid of the refuse, and must also be strongly condemned upon sanitary grounds when there is *any probability* of the area so filled up being built upon.

In a large town where the summer death-rate from infantile diarrhœa for several successive years for children under one year of age was as high as 209 per 1000, the cause of the disease, after a Local Government inquiry, extending over several years, was attributed to the fact of the existence of an enormous number of old brickfields surrounding the town, which had, from time to time, been filled up with town refuse.

It was stated, in the report of the Government Inspector, that "from the contained organic matter of particular soils, micro-organisms are generated capable of manufacturing in the soil by chemical changes (through certain of their life processes) a substance which is a virulent chemical poison, which poison in the human body is the material cause of epidemic diarrhœa."

The Medical Officer of Health reported to the effect that "in those districts where diarrhœa most prevails, the atmosphere is contaminated with enormous numbers of microbes and their germs, and that these latter are in all probability the prime factor in the causation of the disease."

With a view to the prevention of the erection of buildings upon insanitary sites, the following model by-law has been framed by the Local Government Board, and is included in the series relating to "New Buildings." "A person who shall erect a new building shall not construct any foundation of such building upon any site which shall have been filled up with any material impregnated with fæcal matter or impregnated with any animal or vegetable matter, or upon which any such matter may have been deposited, unless and until such matter shall have been properly removed, by excavation or otherwise, from such site."

Knight's "Annotated Model By-Laws" contain the following interesting note upon this important clause:—"From a report made by Professor Burdon Sanderson, M.D., and the late Professor Parkes, M.D., on the 'Sanitary Condition of Liverpool,' experiments, having for their object to ascertain what the effect of lime had been on the organic matters which, together with cinder refuse, had been used to fill up inequalities in the ground, tended to show that '*the process of decay of all the most easily destructible matters*,' including vegetable refuse, '*is completed in three years*.' In the case of wood and woollen cloth the process was more prolonged. The report further states that 'the vegetable and animal matter contained in the cinder refuse decays and disappears in about three years, and is virtually innocuous before that time.' It may therefore be assumed that for practical purposes three years will amply suffice for the removal by oxidation of the objectionable matters in such refuse. If, however, fæcal matter has at any time formed part of the refuse, more stringent precautions ought, for obvious reasons, to be taken; and even after a lapse of a much longer period, all soil which has been contaminated by such matter should be removed before building operations can safely be sanctioned."

A considerable proportion of *London* refuse is disposed of by carting and barging away to waste and marsh lands outside the metropolis. Large quantities are used in raising low-lying lands adjoining the banks of the Thames; as, for example, at Dagenham Breach, Rainham Marshes, Purfleet, and many other places.

It is customary for the owners of "shoots" to charge a small sum (say from 3d. to about 6d. or more according to circumstances) per load deposited, and where this charge continues to be moderate, and the distance to the site not productive of a prohibitive expense in carriage, this method of disposal will generally be found to prevail.

Disposal to Brickmakers.—The brickmakers in the immediate neighbourhood of a town usually find themselves in a position to be able to quote very favourable prices for the removal of dust, owing to the fact of the refuse being utilised by them for brickmaking purposes.

The refuse is conveyed to the brickyard in its rough state and sifted through a fine screen. The fine ashes, or sifted portion, is mixed with the brick and forms the "firing" element, whilst the "breeze," or cinder portion, is used for firing the kilns when the bricks are in the "clamp." The remainder of the refuse, consisting mostly of old meat tins, rags, paper, &c., is placed in a heap and burnt, the residuum being utilised for hard core on second-class roads.

Disposal at Ealing.—At Ealing the house refuse is mixed with sewage sludge from precipitation tanks and burnt in a seven-cell destructor of the Manlove, Alliott, and Co. type, the waste heat being utilised for raising steam to work machinery for treating sewage, pumping, &c., and, as an adjunct, for electric lighting purposes. The process of treatment has been fully described in a paper read[1] before the Association of Municipal and County Engineers by Mr. C. Jones, M. Inst. C.E., Engineer and Surveyor to the Council, as follows: "It has been usual with us to mix our sludge with the house refuse after taking out the rougher materials, such as pots, kettles, &c. For some years this mixture was readily taken by the farmers in the neighbourhood, who paid us a small sum per load for the material. Gradually, however, as farmers and arable land became scarce, and bricks and mortar took the place of corn, the difficulty of dealing with this material grew very rapidly.

"The little ground that was left in the neighbourhood upon which farm produce was formerly grown was taken up by market gardeners, who had no great love for this material, for although the land was somewhat heavy, cabbages and plants of that character are not benefited by cinders and ashes; consequently we were compelled to alter somewhat our mode of mixing the material. Eventually the demand became so small that we had to look the difficulties of the case fairly in the face, and endeavour to find a remedy. This remedy I unhesitatingly state has been found in the use of a destructor. I lay no claim to anything novel; the destructor has been used for some years in the North, and I am only surprised that its application and suitability was not more readily seen. Its utilisation in the particular way in which we use it is, I believe, a new application of its powers. So far as the mixture is concerned, we do now exactly as when the farmer took our material; the ashes are formed in what we call "stanks," the sludge is emptied into these stanks and mixed with ashes, and the material drains itself so as to be just movable, and in that condition it goes into the kiln. Everything of an organic nature is destroyed, and we get a residuum of hard clinker, about 25 per cent. of the material deposited in the kiln. This residuum is valuable for various purposes. We are accumulating it now for road-making. It is also ground into sand for builders' use, to which it is most admirably adapted. It makes excellent mortar, and in these various ways becomes a source of revenue instead of continual expense.

"On the question of nuisance arising, I must distinctly say there is nothing for any nuisance to arise from in the use of the destructor. On only one occasion has any injurious effect arising from the use of the apparatus been discovered, and for that there was a cause, namely, the furnaces had been kept alight too long, having been used without intermission for three months. The only difficulty which I really find is that I have not sufficient cells to do my work thoroughly, and no doubt before very long it will be necessary to work two or four more cells. This is not a matter of great expense, as the principal work has already been done. The shaft, which is 143ft. in height, is suitable for a dozen cells, should they be required. The boiler fixed in position is also an expense completed, and the same may be said of the engine and water mill connected with it. I consider, properly fixed and properly worked, it would save in a moderately large establishment all cost of fuel for boiler purposes. I may add that the experiment thus carried out at the Ealing Works in connection with the destructor has attracted much attention in various parts of the Home Counties, and especially in the Vestries connected with the Metropolitan Board of Works.

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[1] In May, 1884; see "Proceedings" Association of Municipal and County Engineers, vol. x., page 202.

"The dust-bin nuisance, and the difficulty of finding suitable tips, is growing day by day, and I have no doubt that the destructor will be very much used for the purpose indicated. To some of you, however, its application as a sludge destroyer may be more important than in any other light, and I cannot but again express my conviction that it is a simple and ready means of dealing with this difficulty."[1]

Disposal at Leyton.—House refuse in this district is used as a medium for the disposal by cremation of a more troublesome form of refuse produced at the sewage outfall works, viz., pressed sewage sludge cake. This material is mixed with the house refuse, approximately in the proportion of two parts (by weight) of the latter to one of sludge cake, and is effectually consumed, without a trace of nuisance, in an 8-cell Beaman and Deas destructor, leaving a residuum, in the shape of a good saleable clinker and ash, of about 25 per cent. of the original bulk.

The heat thus generated is applied in keeping up steam in a pair of Babcock and Wilcox tubular boilers, the power from which is utilised for driving fans for forced draught to the furnaces and for working mixing machinery and pumping low-level sewage at the sewage disposal works.

This process has been in operation since October, 1896, with the most satisfactory results, and, being of a novel character, has, judging from the numerous deputations, &c., constantly applying for permission to visit the works, excited considerable interest throughout the United Kingdom.

Barging Away.—A large proportion of the refuse of London and other large towns is removed by barging away on canals or rivers to shoots in the adjacent country. The cost per ton for disposal by this means varies considerably in different places, according to circumstances. The Vestry of Kensington pay 1s. 11d. per load shot into barge on river and 2s. 4d. per *ton* on canal. The cost in Bermondsey is about 2s. 9d. per ton, in Battersea 2s. 8d., and in Hammersmith 2s. 8d. In the provinces the cost is less, being about 6d. per ton at Blackpool, 1s. 8d. to 1s. 6d. per ton at Birmingham, and 1s. 10d. at Huddersfield. In Manchester the charge is 1d. per ton per mile by boat and rail.

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[1] Although the foregoing description was written in 1884, I am informed by Mr. Jones that there is no material change in the mode of treatment at the present time, except that a population of some 10,000 more than in 1884 is now being dealt with, and that the residue is now being more thoroughly utilised.

It will thus be seen that the disposal of house refuse by barging away is, generally speaking, and especially so in the metropolis, a very expensive process as compared with its destruction by fire, which can be effected at an average cost of about 10d. per ton, exclusive of interest and sinking fund on cost of works.

Taking out to Sea.—For many years past the bulk of the house and trade refuse of some large seaport towns, such as New York and Liverpool, has been disposed of by being barged away to sea in specially designed hopper barges, and sunk in deep water. Mr. H. P. Boulnois, M. Inst. C.E , gives the following description[1] of how this work is carried out in Liverpool:—"There are at present two special steamers belonging to the Corporation of Liverpool employed in this work, which are named the *Alpha* and *Beta*, carrying, when fully loaded, 330 tons and 400 tons respectively. Each vessel has a large central well or hopper divided into ten compartments, with vertical or slightly undercut sides; every compartment is provided with a pair of doors, each about 10ft. by 4ft., hinged to the keel and bilges, which can be raised and lowered by chains through gearing worked by a small engine specially provided for this purpose. The vessel employed at the north end of the town was originally intended to be loaded direct from the scavenging carts, but as it was found impossible to obtain a quay berth from the Dock Board, it became necessary to load the vessel from canal barges, which was originally carried out at night by thirty-five men shovelling the material on board. This was an exceedingly slow and costly process. Consequently, for some time past special iron canal barges have been employed, each carrying about 50 tons of material, and fitted with large light steel and steel-framed wooden boxes, each box holding, when full, about 2 tons of refuse. These canal barges are loaded with the refuse at certain depôts upon the Leeds and Liverpool Canal from the scavenging carts, which tip over projecting cantilever platforms directly into the boxes in the barge. When the barge is loaded it is taken down the canal to the dock and brought alongside the steam hopper barge, the hopper of which is 60ft. long by 16ft. wide. At first considerable difficulty was found in designing a light and simple loading arrangement capable of being fixed on an already completed vessel, and which could discharge the contents of the boxes at any point within the hopper area. Ultimately it was decided to fix a large boom or derrick, 65ft. long, to the mast, and to work it from a double-barrelled deck winch, one barrel being used for lifting and lowering the boxes, and the other for slewing the boom out-board and inboard as required, by means of a steel rope and outrigged arms. This arrangement is worked by one winchman and four labourers, who hook on and tip the boxes; and on several occasions no less than 55 tons have been discharged from the canal barges into the hopper barge within seventeen minutes.

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[1] See pamphlet cn "The Disposal of Town's Refuse." (The St. Bride's Press, Limited.)

"The boxes are hung on bearings at about one-third of their depth from the bottom, the steel arms from which they are suspended rising slightly above the top of the boxes and finishing in an eye fitting into a notch in the top of the beading of the box. Instead of the usual hook on the end of the hoist rope from the winch, a lever arrangement is provided, common to all the boxes, which is easily hooked on to the eyes of the arms. When a box is over the hopper it is only necessary to depress the lever; this throws the side arms clear of the box, and allows it to tip over, which, after discharging its contents, returns to its original position, when the arms slip into the notches and the box can be returned to the canal barge and lowered into its place without any difficulty.

"The vessel known as the *Beta* is loaded in this way. The vessel known as the *Alpha* is loaded direct from the scavenging carts at one of the southern docks, as a quay berth has been found for her where this can be effected."

Each hopper makes an average of four journeys per week, and when loaded proceeds to the deposit ground in the Irish Sea outside the North-West Lightship, at a distance of about 24 miles from St. George's Pier (Liverpool), the landing stage. The deposit ground consists of about 117,000 acres of sea bottom, at a depth of from 20 to 30 fathoms below the level of low-water at spring tides. "The refuse is discharged by lowering the doors, and allowing the material to pass through, after which the doors are again raised and the vessel returns to the river, the total trip occupying about seven hours. She then awaits the opening of the dock gates, and returns to her berth.

"During the year ended 31st December, 1891, 145,032 tons of refuse were deposited in this manner, costing (including loading into barges) about 1s. 6½d. per ton.

"There is no doubt that for seaport towns this method has considerable advantages; but there is always some difficulty experienced with the lighter descriptions of material, which float upon the water," and the Corporation are now contemplating sending only burnt refuse from the destructors to sea, in consequence of complaints of these lighter kinds of refuse being washed on to the Welsh coast.[1] "It is also stated that fishing with trawling nets is much interfered with, owing to the tinned-meat cases and other materials sinking to the bottom and interfering with the nets."

A further difficulty experienced is that in severe weather the hoppers cannot go to sea, sometimes for several days together, the result of which is the accumulation of large quantities of refuse on the dock wharf, which it is afterwards found difficult to get rid of. The working expenses of each hopper amounts to about £30 per week.

In Liverpool, also, some of the refuse, consisting chiefly of sweepings from paved streets, stable manure, and fish offal, is tipped into barges and sold to farmers along the canal banks for agricultural purposes.

Utilisation—Sorting.—A system for the disposal of house refuse by "sorting" and selling the ingredients has been adopted by the "Refuse Disposal Company, Limited," at their works, Salopian Wharf, Lots-road, Chelsea. The sorting is all done under cover, and chiefly by the aid of machinery. The dust arising in the process of turning over is drawn into the furnace draughts by means of exhaust fans, thereby avoiding nuisance therefrom to the neighbourhood. All refuse is dealt with as soon as delivered to the site, so that accumulations are avoided. The process has been reported on by Sir Douglas Galton in the following terms:—

"The dust carts deliver their loads into a *revolving cylinder* 10ft. diameter by 12ft. long. This cylinder is made of iron ribs placed about 10in. apart, upon which are fixed wooden bars, between each of which is an opening of 2½in. wide, so that anything less than 10in. by 2½in. will pass through. The wood is used to prevent bottles from being broken. The cylinder is supported on friction wheels, and is driven by external gear. It has no internal spindle, or arms, as these would catch the materials and clog the working. It has a tilt of about 9in. in its length. There is a worm carried round the inner surface of the cylinder, with an interspace of 2ft. 6in. for the purpose of assisting the material in travelling through the cylinder. Thus, material thrown in from the dust cart will pass out at the further end in from two and a-half to three minutes.

"The material which does not drop through the meshes of the cylinder is taken out and sorted by hand as it arrives at the further end, consisting chiefly of cardboard boxes, bottles, fuel, tin boxes, clothes, and other various matters; these are all sorted into separate baskets, the vegetable and animal refuse being taken to a mill to be ground. The material which falls through the first screen passes into a second screen, which consists of a cylinder of iron 8ft. diam., 16ft. long, covered with wirework having a mesh of 1¼in. square. This cylinder is also supported on friction wheels, and driven by external gearing, and is provided with a worm to carry the materials which do not fall through the meshes from one end to the other. This material, as it falls from the end of the second cylinder, is met by a powerful blast of air, which blows the paper away from the heavier material into an iron chest, where it is subjected to heat from the exhaust steam which is passed through the pipes in the chest. The other heavier material is raised by an elevator into a slide placed at such an angle as to regulate its descent on to an iron horizontal plate or table, which is constantly revolving, and which brings the material to a series of boys sitting round, who sort what lies on it.

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[1] Cardiff Report on "Refuse Disposal" (1897), by W. Harpur, M.I.C.E.

"Thus coal is all saved, so is iron and metal, also boots and shoes, whilst nondescript material, such as bread, vegetable and animal refuse, broken crockery, &c., is all taken to the grinding mill and ground up with similar refuse from the first cylinder. The material which drops through the second cylinder is delivered by an endless band into a third cylinder, also of iron, 6ft. in diameter and 15ft. long, covered with wirework having a mesh of ⅜in. This cylinder is also furnished with a worm. What passes through this mesh is called *fine ash*, and is sold to brickmakers. The refuse which is delivered at the end of this third cylinder, and has not passed through the ⅜in. mesh, but has passed 1¼in. mesh, forms the fuel for working the engines for the operation, and also is sold as fuel for brickmakers. This latter refuse contains much vegetable matter. It would appear, from statements made as to the quantity required under the boiler, that its value was about one-seventh that of coal; but its heating power is much increased by washing, which removes potato peelings and other vegetable refuse; and, indeed, part of the process is to expose the material to a stream of water which carries off the lighter organic matter.

"It should have been mentioned that the dust which is occasioned by the process of working in the cylinders and in the spaces below them, is removed by a powerful exhaust[1] acting through apertures which open into the centre of the cylinders and into the other spaces, where the movement of the material generates dust. The exhaust carries the dust through the fire, which is under the boiler. By this means the operators are relieved from exposure to the dust caused by the operations. A market is said to be found for all the sorted refuse. For the ground-up material from the mill there appears to be a demand from manufacturers of manure. The paper, after it has been dried at a high temperature, which can be made sufficiently high, if desired, to remove chances of infection, is sorted and freed from dust, and is then pulped for conversion on the premises into brown paper or cardboard. There seems to be no reason, if care were taken to sort out the best white paper, why this better material should not be converted into white paper, instead of all being converted into brown paper and cardboard, as is now done.

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[1] Extracting about 7000 cubic feet of air per minute.

"The dust which is drawn by the exhaust from the cylinder and from the paper chest, and from other parts, is all drawn through the boiler fire, the accelerated draught of which assists the combustion of the vegetable refuse in the breeze, and enables the gases from the fire to be passed through a scrubber with water spray, so as to prevent offensive odours. It may be mentioned incidentally that the works are lighted by electric light, generated by the fuel obtained in these operations.

"The question of dealing with this class of refuse has always been a troublesome problem. The plan of burning the refuse does not do away with a certain amount of preliminary sorting; this sorting, as usually practised, is necessarily an insanitary occupation, and the wholesale burning of refuse is undoubtedly wasteful. The plan proposed is based upon the principle of removing insanitary conditions from the arrangements for dealing with this class of refuse. It prevents injury to the dust sorters, because whilst the refuse is sorted by mechanical appliances, the dust which arises in the necessary manipulation of the material in sorting is removed by a powerful exhaust, and thus the atmosphere in which the operations take place is kept pure. The method adopted for mechanical sorting saves all those portions of the refuse that can be utilised, and it employs for the purpose of its own operations that part of the material which cannot be sold, but which has finally to be disposd of by burning. In fact, whilst it utilises the waste products, it aims at placing the method of disposing of this class of house refuse in the category of a *healthy occupation*[1]; and it may be safely asserted that it has achieved this object even in the rough preliminary arrangements which have been made at the Salopian Wharf—arrangements which might, no doubt, be greatly improved in any fresh installation."

The process of "sorting," &c., by the Refuse Disposal Company, will be more readily followed by the typographical diagram[2] given on the next page, of which the top ("dust") indicates the beginning of the operations—"A" being the "revolving cylinder" into which the dust is delivered.

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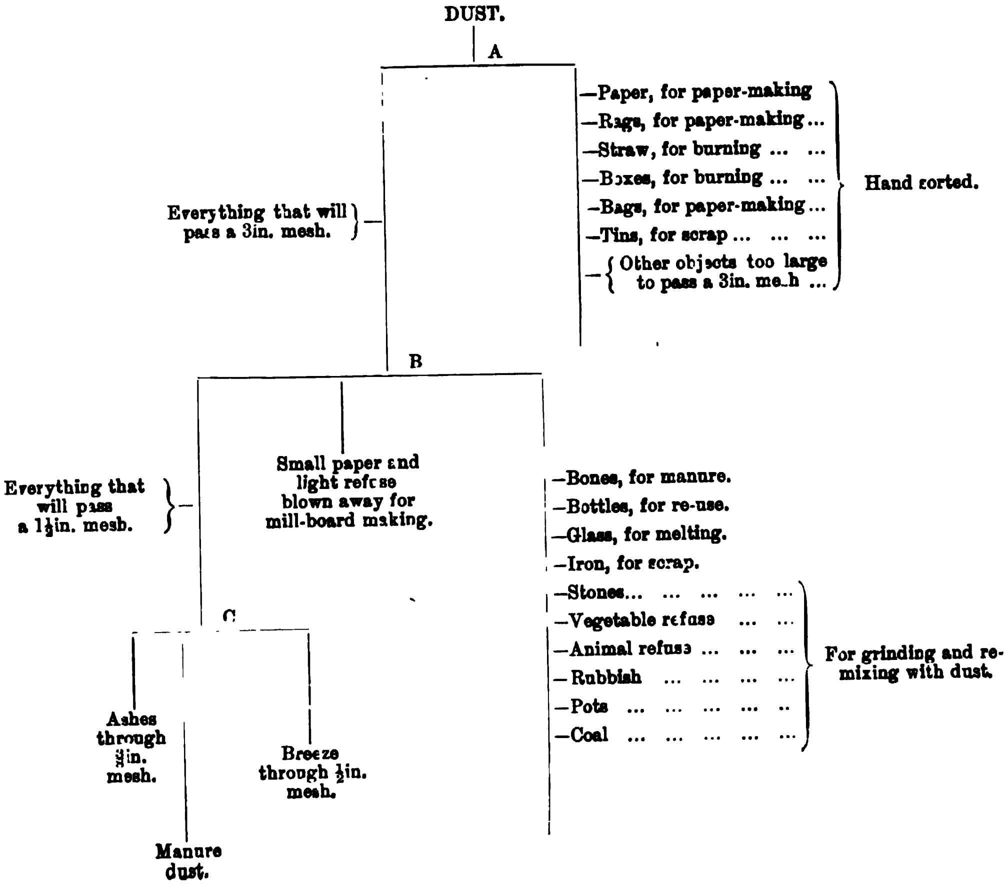
[1] It is stated that nine-tenths of the material is sorted *without touching* by hand, and the remaining one-tenth only after it has been well dusted and cleansed.

[2] From "Professional Papers of the Corps of Royal Engineers," edited by Capt. W. A. Gale, R.E. 1891.


DUST.
A
—Paper, for paper-making
—Rags, for paper-making ...
—Straw, for burning ... ...
—Boxes, for burning ... ...
—Bags, for paper-making ...
—Tins, for scrap ... ...
—Other objects too large to pass a 3in. mesh ...
Hand sorted.
Everything that will pass a 3in. mesh.
B
Small paper and light refuse blown away for mill-board making.
—Bones, for manure.
—Bottles, for re-use.
—Glass, for melting.
—Iron, for scrap.
—Stones... ... ...
—Vegetable refuse ... ...
—Animal refuse ... ...
—Rubbish ... ...
—Pots ... ...
—Coal ... ...
For grinding and re-mixing with dust.
Everything that will pass a 1½in. mesh.
C
Ashes through ⅜in. mesh.
Breeze through ½in. mesh.
Manure dust.

Dr. Joseph Russell, after some years' experience in his "sorting" process at Chelsea, summarises the principal constituents[1] of house refuse and the uses to which they may be put as follows[2]:—

Paper and rags are made into a common brown paper or leather board.

Straw and fibrous material and small pieces of paper for strawboards.

Woollen rags are sold for shoddy.

Large coal and coke, sold.

Iron, sold.

Bottles are sold for re-use, &c.

Crockery has been sold for re-manufacture. Offers have also been made for it, if broken up and sorted into sizes, for use in tar paving instead of marble chips.

Ashes and Breeze into block fuel for steam purposes, or for electric lighting, or for brickmakers.

The Vegetable and Animal Substance, with the fine dust and the bones, for agricultural purposes, or as a basis for distributing strongly-concentrated manure (such as nitrate of soda).

Mineral, such as the clinkers, stones, &c., for concrete blocks or artificial paving stones.

The Clinkers being very hard are also suitable for mortar, or to use in lieu of sand on wood and other roads.

Broken Glass can be re-made into bottles, &c., or used for making glass-paper, or as a flux.

Tins, these by a simple process can be cleansed from the fats adhering to them, and the solder run off and collected,[3] whilst the plates are melted and run into sash weights or slabs; or the plates can be bundled up and sent to the mills to be re-forged.

In addition to the above, large quantities of *stones* are taken off the revolving table, and are always useful for foundations of roads, concrete, &c.; also other metals than iron, as mentioned, are frequently met with, such as copper, brass, lead, and occasionally silver.

As regards the "ashes" passed through a ⅜in. mesh, Dr. Russell states that besides being useful for mixing with brick clay, it also "forms the fuel for the boilers to provide steam for the works; and although at first great difficulty was experienced to maintain steam, yet since the introduction of a patent steel fire-bar, with a forced draught, this trouble has been entirely overcome, and there is not the slightest difficulty in maintaining the steam pressure required.

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[1] For analysis of London refuse, with the proportions of the various constituents, see *ante*.

[2] *Sanitary Institute Journal*, vol. xiii., page 55.

[3] Messrs. Manlove, Alliott, and Co., Limited, have invented a small *furnace* for the recovery of tin and solder from old cans.

It has also been found that on account of the very small surface of bar in contact with the fuel, and the very large volume of air in numerous and fine streams, and that also heated, the combustion is practically perfect. Another great advantage is also obtained, the clinker (of which there is about 30 per cent.) does not adhere to the fire-bars, and can be removed with the greatest ease. The products of combustion can be finally passed through scrubbers before discharging them into the air."

A load, or ton of refuse, from the time of being shot from the cart will, it is stated, pass through and be sorted into its various places in from five to seven minutes.

For this system it is urged that there is a *use* for every portion of the house refuse, and when thus sorted and dealt with, the products resulting possess a commercial value sufficient to pay expenses of manipulation, and leave a "handsome profit" on the undertaking; whilst other modes of disposal, such as "shoots," barging, carrying to sea, and cremating in destructors, are carried out only at a considerable loss.

Mr. W. Harpur, M. Inst. C.E., Borough Engineer of Cardiff, has recently had occasion to inquire into and report upon the company's process of utilisation, and has estimated that, were this business adopted in Cardiff, and the disposal of the products obtained placed in proper hands, the annual income derived from their sale would be about £8600. It was further calculated that, supposing this return was only one-half realised (or £4300 per annum), even then, after deducting for repayment of principal and interest on the loan for machinery and buildings, fuel (which would be that screened from the refuse) and labour, which together may be put down approximately at £2300, there would still be a net profit on the undertaking of about £2000 per annum, which was considered quite a reasonable anticipation.

The prices per ton attached to the saleable articles mentioned in the above estimated return were:—

	£	s.	d.	
Crockery	0	1	0	per ton.
Iron	1	10	0	„
Tins	1	0	0	„
Broken glass	1	10	0	„
Straw and fibrous material	1	0	0	„
Waste paper	2	0	0	„
Rags	3	0	0	„
Coal and coke	0	5	0	„
Cinders	0	2	6	„
Animal and vegetable matter ground as manure	1	0	0	„
Bones	3	15	0	„
Bottles	0	0	3	per dozen.

No difficulty whatever was anticipated in finding a market for all these materials at the prices named.

In laying down any new installation of such a depôt as that at Chelsea, the first thing to be done, it was observed, would be the erection of steam boilers and engines for driving the necessary machinery; and since the provision of one or two additional machines would make but very little difference in the working expenses, but would probably considerably augment the income of the undertaking, it was thought desirable, the necessary motive power being available, to erect a small paper-making apparatus and a bone-crushing machine on the premises, so that the works may be capable of sending out the articles referred to in a more valuable and marketable form.

It is also suggested that in the winter time, when heavy falls of snow occur, *and the collection of house refuse practically ceases for a time*, most of the machinery being idle for want of supplies, the waste steam might to advantage be used for melting snow brought into the depôt; but as it is proposed that the *fuel for steam* be derived from the house refuse, it is difficult to see how steam is to be raised under these circumstances.

It was also observed that, in addition to the plant erected at Chelsea, it would be essential in any complete arrangement of the kind to erect a small *destructor*, in which would be consumed such refuse as is unsaleable (and of which it was considered there would certainly be a small portion), and articles which it would not be safe or prudent to dispose of, as infected bedding, &c., and also (if deemed advisable) the whole of the refuse from any district of the borough infected by a serious fever epidemic.

An important question connected with works of this kind is whether the business can be carried on continuously without creating a *nuisance*. The following extract from a circular issued by Dr. Arthur is directed towards the settlement of this point:—"In dealing with refuse the most important and vital point of sanitation arises. We unhesitatingly claim that our process is highly sanitary and inodorous, and our reasons for this are as follows: (1) By our patent forced draught we, from the very beginning of the process, catch up and convey to the furnaces all dust and smell; (2) our rapid manipulation of the refuse, from the moment of our receiving a load of dust until it has passed through the machinery, separated, and cleansed, is a period of seven minutes only; (3) all vegetable and animal refuse at a particular point of the process is, after being thoroughly cleansed of dust, &c., passed at once into the powerful mill and ground up."

Independent testimony as to the absence or otherwise of nuisance from the process as carried out by Messrs. Russell, at Chelsea, was obtained by Mr. Harpur from Mr. T. W. Higgens, Surveyor to the Vestry of the Parish, and from Dr. Louis E. Parkes, the Medical Officer of Health.

The former said, in November, 1894, that "some time ago complaints were made of smells from the chimney of the Refuse Disposal Company on two occasions, and it was found that they were burning some refuse in their furnaces; but I have not heard of any complaint from their disposal system nor from their chimney for some years."

The reply of Dr. Parkes was as follows:—"In 1890 the Chelsea Vestry instituted proceedings against this company for the emission of effluvia from their chimney shaft, but the case was abandoned on the company's undertaking to abate the nuisance and pay costs. On several occasions in the years subsequent to these proceedings I have received complaints of the emission of offensive odours from the company's works, but there has been no further prosecution. I believe the nuisance arose from defects in the plant in use, especially deficient height of chimney shaft and scrubbers not always in use. The operations of the company have been of a limited character recently, and no complaints have been received during the past year (1893—4). I should think that with efficient appliances and care in work, the processes carried on by this company could be conducted without generating any nuisance in the neighbourhood."

Of late years the works have doubled in area, entirely are remodelled, and most of the machinery renewed. Also the company has now ceased professing to make manure, and the whole of the dust, to which also is added the larger particles of animal and vegetable matter and other refuse, taken off the sorting table after being ground up in a mill, is passed through the washing machine, and reduced to what the company term their "washed carbon."

The paper mill has also been entirely reconstructed, and now produces an excellent brown paper at a profit of from £2 to £2 10s. per ton, made entirely out of the paper, rags, &c., obtained from the refuse.

Sorting Process at Vestry Wharf, Paddington.—The refuse, as collected throughout the parish, is at present brought to the Vestry's wharves on the canal basin, and the rough dust from the dwelling-houses is tipped on to the grating of the sifting machine. Whilst there it is forked over, and all that will not pass between the bars of the grating is drawn to one side and hand-picked. The "soft core" thus obtained is loaded into barges to be removed into the country, where some of it is used as manure. All matters passing between the bars of the grating are lifted by an endless chain of scoops on to inclined sieves moved by steam power, the "ashes" sifted out falling to one side, and the "breeze" to the other. The siftings are again hand-picked, and any garbage found in them is loaded into the boats containing the soft core. The ashes and breeze are finally shot by the machine into barges and sent away to the brickfields. Except when the canals are closed by ice or the sifting machine disabled, the rough dust does not remain on the wharves for more than a few hours. The existing machine can deal with twenty-five chaldrons of rough dust per hour, and the greatest amount brought to the wharves in a working day has been 180 chaldrons. Trade refuse, such as fish offal and the like, is loaded into barges with the road sweepings.[1]

The chief advantage and disadvantages of the system, as reported recently by a special sub-committee of the Vestry, are briefly as follows:—

Advantage:

Everything having a *market value* is picked out and sold; especially the ashes and breeze, also old bottles, rags, &c.

Disadvantages:

(1) Excessive handling of the refuse, scattering of dust, and increasing risk of spreading disease.

(2) Dangers to public health inherent to carting through streets of rags, paper, &c.

(3) There is a yearly decrease in the market value of the manufactured refuse, and the soft core (the most objectionable) is only removed at great cost.

(4) Removal by canal is uncertain in winter, by reason of liability to stoppage by ice, thus causing objectionable accumulation of refuse at the wharves.

(5) Increasing difficulty of securing "shoots"[2] for refuse after barging away.

Although the arrangements at the Vestry's wharf were found to be carried on in a systematic and efficient manner, as compared with those at the wharves of Messrs. Hobbs and Sons and Messrs. Mead and Co. (both of which are situated within the parish of Paddington), it was considered that the process of "sorting," &c., left much to be desired, and the committee therefore came to the conclusion that it was of vital importance to the health interests of the parish that some plan should be adopted for burning their refuse directly it arrived at the wharf.

Dust Contractors' Yards.—The processes carried on in a London dust contractors' yard have been thus described by Dr. Ballard:—

"On a load of dust being upset from the dust cart upon the surface of the yard, some men and boys proceed to sort it. They are each provided with a fork and an instrument called a 'drag,' which has a short handle and three cast iron teeth, set about 3in. apart, and with these they fork and drag the heap over, so as to separate from it obvious pieces of vegetable and animal refuse, bones, rags, paper, iron, crockery, and glass. These are distributed, some of them into heaps, others of them into baskets; the bones are put into a bin or heap in the yard by themselves for sale to bone boilers. The rags and paper are also usually set aside for sale, the iron and old tins are always set aside for sale, and usually also the glass, while the broken crockery, brickbats, &c., are laid in a heap to be sold as material for making new roads. What is left consists of cinders, ashes, and little bits of unburnt coal, and the next process is to sift this. The sifting is performed usually by women, who sit on or close to the heap, having one or more baskets by their side, and a riddle in their hands. A shovelful from the heap is shaken in the riddle, and, the ashes and dust having passed through, what remains upon the riddle is examined, and bones, potatoes, bits of iron, &c., not removed by the first dragging process, are picked out and thrown each into its appropriate basket; the cinders and coal now remaining on the riddle are thrown on a separate heap, being then technically known as 'breeze.' The following are the terms under which the matters of a dust heap are known technically, after they are separated from one another:—'*Soft core*,' *i.e.*, vegetable and animal refuse; '*hard core*,' *i.e.*, broken crockery, brickbats, &c., and sometimes glass, old shoes, bits of rag, &c.; '*breeze*' and '*ashes*.'"

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[1] The *Surveyor*, April 9th, 1897.

[2] Diphtheria has been shown to occur with undue frequency in the immediate vicinity of London refuse heaps.

The offensive and degrading nature of the work carried on in the dust yard will be apparent from the description of the *City dust yard* at Lett's Wharf, Lambeth, as contained in a report by Dr. Sedgewick Saunders, the Medical Officer of Health and Public Analyst for the City of London, presented to the Honourable the Commissioners of Sewers in July, 1881. He says: "When the dust carts arrive at the wharf, their contents are tipped into heaps at the place most convenient for the people who are employed as sorters. About seventy persons, chiefly women, are engaged in this degrading and loathsome work; most of whom are paid by piecework, but sixteen female sifters receive 7s., and a little coal and wood, weekly. The appearance of these women is most deplorable; standing in the midst of fine dust piled up to their waists, with faces and upper extremities begrimed with black filth, and surrounded by, and breathing, a foul, moist, hot air, surcharged with the gaseous emanations of disintegrating organic compounds, they resemble the denizens of the place said to be paved with good intentions, rather than the image of their Maker. [I shall never forget visiting some of these poor creatures in hospital, and witnessing the condition of their skins, when the accident to the chimney shaft occurred.]

"The dust is placed into large circular sieves, which are worked by the sifters and divided into two portions:—(1) The finer part, which falls at the feet of the operators, and partly buries them; (2) the coarser part, which is thrown on one side for the next process. This consists in the separation and sorting of the larger articles, such as clinkers, bottles, old metal, crockery, paper, corks, bones, rags, string, &c., which are industriously placed in distinctive heaps for sale. The sifters and sorters are employed by a general contractor, to whom the Commissioners pay 9d. *per load* for the work, the contractor taking, as well, the paper, *whole* bottles, rags, iron, tin, &c., but leaving the *breeze* (cinders and particles of unburnt coal), *soft core* (animal and vegetable and textile substances), and *useless* hard core (worn out pots and pans, and large articles). This payment of 9d. per load amounts to from £20 to £25 per week. The scraps of paper fetch from 25s. to 30s. a ton; rags, 20s. a ton; bones, 50s. a ton; iron, 20s. a ton; metal 18s. per cwt.; tin-ware, 3s. a cart load; corks, 1s. a bushel; bottles, 9d. a gross. The barges are loaded with the breeze and fine ash in the proportions of one to two, and sold to brick-makers from 2s. to 2s. 6d. per chaldron (barges hold from sixty to seventy chaldrons). The *hard core* (clinkers, broken bottles, and crockery) is used for road making, and the Commissioners have frequently to pay the barge owner 50s. a barge load for its removal; about one load a week is thus disposed of. As far as I can ascertain, the expense incurred in the work includes — a general manager and salesman, at £225 per annum; a ganger, at 50s. per week; twelve men at 5d. an hour, day work, or 3d. per chaldron for stuff shot into the barges; a lighterman, to look after the barges and berth them, at 35s. a week, and a house; and a furnace man, at 4d. per hour, ten hours a day. These charges are irrespective of the general staff of the yard, and those employed outside its walls."

The city dust, said a recent article in *London* on the work of the City Commission of Sewers, which is now transferred to the Corporation, still affords ample scope for the golden dustman. The women and boy sorters at Lett's Wharf, where the dust and refuse is carted, find many valuable articles in the dust. Among the finds during the twelve months ended September, 1897, were cheques for the following amounts:—£40, £23 13s., £31 16s., £42 14s., and £3. A reward of 2s. or 3s. was given to the finders. A dividend warrant for £27 brought a reward of 5s. A demand note for £1000 was among the finds, and a guinea was given to the finder; a promissory note for for £706 brought a reward of 5s.; a good deal of money is also picked up. A gold ring was found, and among the other articles discovered have been shares in American railway companies, watches, photographs, set of false teeth, and opera glasses. Such articles are returned, if the owners can be found. Useful things sifted from the dust are sold, a twelvemonth's paper bringing £541 17s.; rags, £47 10s.; bottles, £84 16s.; string, £181 8s.; and books, £24.

The Paddington sub-committee, above referred to, have recently had the subject of refuse disposal under their consideration, and in the course of their inquiries inspected the premises of Messrs. Hobbs and Sons and Messrs. Mead and Co., in North Wharf-road, where the refuse from Marylebone, St. George's (Hanover-square), and St. James's (Westminster) is brought for disposal. The committee state that they found the former of these premises in a most objectionable condition. The yard was strewn with refuse of all kinds, including animal and vegetable, so that it was hardly possible to walk without treading on it, and the smell was decidedly unpleasant. Paper of every description was littered about. In the middle of the yard was a heap of refuse on fire, "a most dangerous and illegal proceeding." At Messrs. Mead and Co.'s wharf the state of things was not quite so bad, still there was much that was objectionable.[1]

The "sorting" of refuse is a degrading occupation, and is open to much objection, as is well pointed out in the report[2] of the London County Council on "Dust Destructors" by their engineer and Medical Officer. It states that "the *women* employed are often seen covered almost to the waist with refuse, and they continually inhale into their lungs air polluted by the surrounding accumulations of dust. From some cause, avoidable or unavoidable, large heaps of material are almost invariably found in a contractor's yard, and even with the best management a long-continued frost must interfere with the process of removal by barge, upon which London is so largely dependent. Again, the progress of offensive cargoes on their slow journey down the canal taints the atmosphere and pollutes the water, and when the destination is ultimately reached, the question of rendering the material innocuous still remains unanswered. It is true that in many instances the sorted refuse admits of useful application, but the supply has been so much in excess of the demand of late years that it not infrequently happens that the bulk of the material commands no price, and the only question is how to get rid of it. Under these circumstances the natural solution is to shoot it in some sparsely-inhabited district where public opinion is not strong enough to effectually resent its being deposited. The method of *destruction by fire* has in its favour the fact that it implies that the refuse is rendered innocuous at the depôt where the destructor is situated,

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[1] The *Surveyor*, April 9th, 1897.

[2] May 10th, 1898.

and in this respect stands in favourable contrast to any plan which necessitates that the processes of decomposition shall be allowed to proceed unchecked for an indefinite period."

CHAPTER V.

REFUSE DESTRUCTORS.

There is nothing new in the general principle of the treatment of refuse by cremation—it is a subject the sanitary importance of which has been recognised almost from time immemorial. Ancient history records that the purification of insanitary difficulties by fire was the mode practised by the Jews, Romans, and Greeks, and also by the natives of India. It is interesting also to notice that among the antiquities of ancient Rome is a pillar bearing the inscription—"Take your refuse further, or you'll be fined."[1] In Jewish history, too, we read that the valley of Gehenna or Topheth, where some of the Jews once sacrificed their children to Moloch, and which was subsequently regarded as a place of abomination, was made a receptacle for all the *refuse of the city* of Jerusalem, and that perpetual *fires* were kept burning in order to prevent pestilential nuisances.

As regards our modern English modes of disposal of refuse by fire, the practice and apparatus employed to-day are, like most other useful inventions, the result of much experiment and very many failures. It would, however, serve no useful purpose to give in detail,[2] even if it were possible, the particulars of all the various furnaces and machines which have from time to time been designed; but a brief summary of some of the more important attempts may be of interest as indicating the course of the development of the cremation of refuse as we now know it.

Ordinary type furnaces, built mostly by dust contractors, were used in London and in the North some forty years ago, but they were unscientifically constructed and not adapted to the proper combustion of refuse. It was consequently found necessary to use coal or other fuel with the collected refuse to ensure its cremation. A furnace of this description was erected by the Corporation of Manchester about the year 1873.

An attempt was made in 1870 by Messrs. Mead and Co., dust contractors, at Paddington, to burn house refuse in closed furnaces. These were soon pulled down, as they failed to burn the refuse for want of draught, which defect was attributed to the furnaces being below the ground level. Mr. Codrington, however, observes[1] that, judging from a drawing, the great defect was want of sufficient area in the flue, which was only 1ft. 9in. square, for 110 square feet of fire grate.

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[1] Lucian's "Ancient Rome in the Light of Recent Discoveries."

[2] For fuller particulars see paper on "Refuse Destructors," "Proceedings" Association Municipal and County Engineers, vol. xiii.

About the year 1876, Mr. Fryer, Nottingham, erected one of his furnaces (which he styled the "Destructor"[2]) at Manchester, and others were added shortly afterwards. The towns of Birmingham, Leeds, and Bradford followed next in the erection of the "Destructor."

The furnace of Messrs. Pearce and Lupton, of Bradford, was invented about 1880, but after a fair trial in that town, conducted by the inventors, the experiment was abandoned.

Pickard (foreman at the Leeds Corporation Destructor Works) invented a refuse destructor which he called the "Gourmond." This furnace appears to have practically embodied the object of the more modern apparatus, the "cremator," in that it aimed at the purification of the gases given off from the cells by the action of fire.

Shortly afterwards Healey brought out his furnace, and a Fryer and Healey destructor was erected at Bradford. In this the purification of the gases was also attempted, but without the desired degree of success.

" Thwaites " apparatus consisted of a combination of a refuse furnace and boiler.

The furnace of Young, of Glasgow, consisted of an ordinary furnace with closed ashpits, into which air was blown by means of a powerful fan to assist combustion.

Mr. J. Wilkinson, of Birmingham, invented a furnace, and one of his type was erected at Blackpool. These furnaces are said to have cost a great deal for repairs.

Burton invented a long single furnace with two fires, the refuse being moved through by means of an endless chain.

The well-known "Bee-hive" was introduced by Stafford and Pearson, of Burnley. The accompanying diagram (Fig. 4) will suffice to illustrate the general arrangement of this destructor as erected in the parish yard at Richmond, Surrey, where two "bee-hives" were erected at a cost of £443 4s. 6d., including a chimney shaft 90ft. high, which were opened in 1884. These destructors were guaranteed to destroy 15 cwt. per hour for each hive, but they were constructionally weak, and the *wrought iron* furnace bars, which were destroyed with the heat in twenty-two weeks, had to be replaced by cast iron bars. The mode of charging the destructor was also faulty, and

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"Report on the Destruction of Town Refuse," by T. Codrington, M. Inst C.E. (1887).

A somewhat inappropriate name, inasmuch as matter cannot be "destroyed," but simply changed in form.

numerous contrivances in the shape of perforated dampers, baffle plates, &c., were inserted in the main flues with the object of intercepting the charred paper, dust, &c. There being considerable local opposition against the use of the furnaces, they were closed in June, 1885.

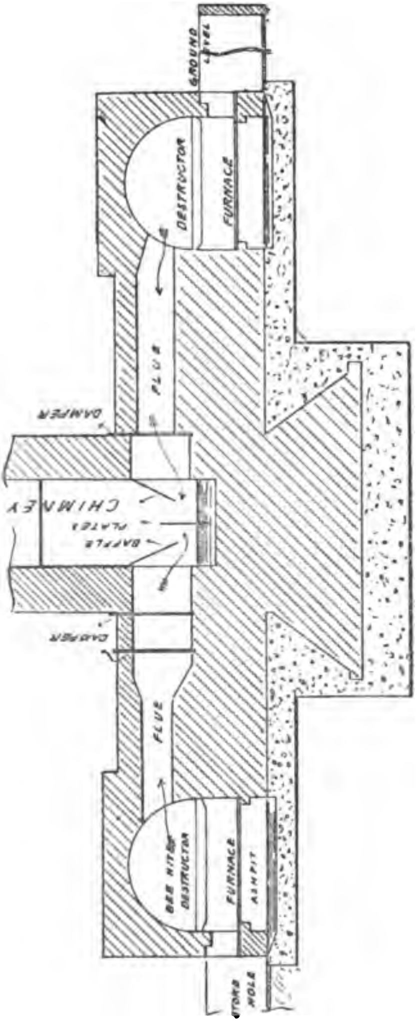

Fig. 4.—Section of the Richmond "Bee hive" Refuse Furnace.

The "Bee-hive" was also erected at Bradford, where it was intended for the destruction of the market garbage and fish refuse, but as "the cost of wages and *fuel* amounted to over 4s. per ton of refuse destroyed, its use was discontinued."[1] The "Nelson" destructor was patented in 1885 by Messrs. Richmond and Birtwistle, and an apparatus of this type was erected at Nelson-in-Marsden (Lancashire), but the construction of a larger destructor of an improved type has since been under consideration. Mr. T. Codrington, in his "Report on the Destruction of Town Refuse" (December, 1887), gives the following particulars as to the Nelson furnaces:—"There are three furnaces placed side by side consisting of horizontal fire grates 3ft. wide and 3ft. 6in. long, separated from each other by side walls, but communicating at the back with one drying hearth. For the purpose of experiment, apparently, the hearth is differently constructed opposite each furnace. Opposite the first it slopes from the back to the fire bars, and has apertures under iron shelf plates to admit heated air to the drying refuse. Opposite the second it is of fire-brick and level with the fire grate, and opposite the third it is sloping like the first, but of solid fire-brick. There are passages in the side walls of each furnace for the purpose of admitting air heated by passing through the walls to different parts of the furnaces. They open just above the fire-bars, and are intended to promote the combustion both of the refuse and of the vapours. The refuse is fed into openings at the back, and slides forward on the drying hearths to the fire grates, the products of combustion passing from the furnaces transversely over the refuse on the hearth, which constitutes, as it were, a part of the main flue. The middle hearth, which is level and forms a hollow between two inclined hearths, is intended for wet garbage, slaughter-house refuse, and excreta mixed with ashes. After leaving the furnaces the gases are passed over a coke fire on a fire-brick hearth, fed from above, and supplied with air through flues opening on a level with the hearth." In a trial in July, 1886, market refuse and garbage were burned at a cost of 2s. 9d. per ton for labour, and 1s. 9d. per ton for the coke furnace; the residuum, clinker, and fine ash, were together over 50 per cent. of the refuse dealt with.

The apparatus invented by Hardie, of Burnley, consisted of an inclined furnace with a saddle boiler over, and it was proposed to dispense with chimneys by adopting the air-blowing principle.

The Borough Engineer of Salford, Mr. Jacobs, designed a furnace for dealing with town refuse and sewage sludge. Its construction was upon the lime kiln principle.[2]

Odgen, of Burnley, introduced a destructor formed with two fires and a boiler over. Among the advantages claimed for it were—the burning of offensive gases by carrying them over a coke fire, and the carbonising of refuse and retention of its fertilising properties.

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[1] "Proceedings" Association of Municipal and County Engineers, vol. xii., page 106.

[2] "Proceedings" Association Municipal and County Engineers, vol. xiii.

Amongst the towns which took the lead in the adoption of refuse destructors may be mentioned Manchester, Birmingham, Leeds, Heckmondwike, Warrington, Blackburn, Bradford, Bury, Bolton, Hull, Nottingham, Salford, Ealing, London, and others. The "destructor" has now become very general throughout the country, and numerous furnaces of *recent type* are at present either in course or at the point of erection, a destructor in large towns being regarded almost as an indispensable item in the list of municipal contrivances.

The best known destructors of the present day will now be described and illustrated.

FRYER'S DESTRUCTOR.

The general arrangement of the Fryer destructor was patented[1] by the late Mr. Alfred Fryer (of the firm of Manlove, Alliott, and Fryer) in 1876, and is illustrated in the accompanying figures (5 and 6).

This type of destructor consists of a block of cells usually arranged "back to back" in pairs, with a flat top, upon which the house refuse is tipped. Each cell measures internally about 9ft. by 5ft., and is covered by a fire-brick arch 3ft. 6in. high above the grates. The bottom of the furnaces, as will be seen from the illustrations, have an inclination of 1 in 3, from back to front; the rearmost or higher position of which, for a width of 4ft., forms a fire-brick hearth or dead plate, and the lower or remaining part, having a width of 5ft., consists of fire-bars. A wall at the back end of the cells divides each furnace into halves; on one side the upper end of the slope is carried up with a steeper slope to a "feeding hole" for the admission of refuse from above, whilst on the other side is a passage forming an opening into the main flue for the escape of the products of combustion. When the cells are placed back to back with the feed-holes adjoining, only one opening is provided for each pair of cells. The main flue, which is of large size, also forms the dust chamber, and is underneath the hearth. Over the middle of one or more of the furnaces, another opening fitted with a cover is provided and through which infected bedding, condemned meat, &c., can be put into the hottest part of the fire. The space thus provided is not usually large enough to be well adapted for the purpose, as bulky articles — as mattresses, &c. — require to be cut up before they will pass through. The refuse in the cells is moved forwards to the fire-bars by raking from below through the fire door and pushing from above. The clinkering is done at intervals of about two hours or when thoroughly burnt. It is removed from the bars and raised through the burning cinders by means of long iron bars or clinkering tools and raked out of the furnace.

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[1] Patent No. 3125, A.D. 1876.

The furnaces have cast iron furnace mouths, with doors 5ft. wide, hinged at the top to open upwards with balance weights.

Both furnaces and flues are, of course, lined throughout with fire-brick.

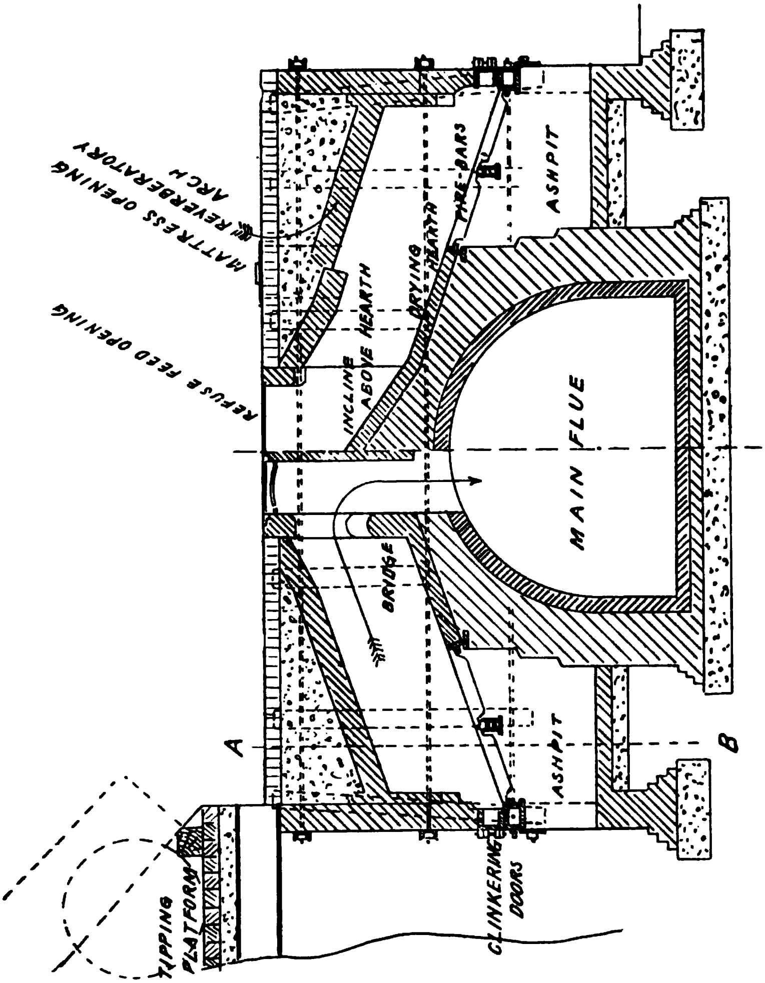

Fig. 5—Section of Fryer's Destructor.

A group of six cells with their enclosing brickwork forms a rectangular mass measuring about 21ft. by 24ft., and 12ft. high. The refuse arrives at the top of the furnaces by means of an *inclined roadway*, generally built between battering retaining walls, which leads to a platform some 2ft. 6in. above the destructor. This roadway, it need scarcely be mentioned, should be of as flat a slope as can be obtained, and in no case steeper than about 1 in 15. Upon a limited site a *lift* or *elevator* is sometimes used to raise the refuse to the top of the destructor, but a cart road is more satisfactory.

To create a good draught and to carry off all offensive fumes, &c., a destructor *chimney shaft* requires to be from 120ft. to about 200ft. in height, and the lower part is usually finished with a fire-brick lining with a 4½in. air space to a height of from 50ft. to 70ft.

"There is one feature in connection with this form of furnace which militates against its use from the nuisance point of view, and it is this, that the outlets for the products of combustion are at the back, and that, whilst a charge is burning upon the furnace bars the next charge lies upon the dead hearth at the back near the outlet flue, where it undergoes drying and partial decomposition, with the result that offensive vapours are given off, and these pass into the flue without being exposed to sufficient heat to render them inoffensive, and in some cases have produced a nuisance. A second furnace called a '*cremator*'[1] has therefore in many cases been placed in the flue leading to the chimney shaft for the purpose of resolving the organic matters present in the vapour; but the greatly increased cost consequent upon the introduction of the cremator has led to its disuse altogether in some cases."[2]

The following observations as to the general methods of *working* the Fryer destructor apply also, with slight modifications to meet special circumstances, to all destructors, and need not therefore be repeated[3]:—

"The cart, on entering the yard in which the destructor is built, is drawn by a horse up an inclined roadway with varying gradients of from 1 in 12 to 1 in 25, and on arriving at the top a platform is provided with tipping curbs, against which the carts are backed, and their contents are tipped on to the top of the cells. Here the material remains for a short time, until one of the cells is ready for a charge, the charging holes being in direct communication with the fire, but so arranged that very little smoke at any time issues from them. When a cell requires to be charged, the material is shovelled or drawn with a two-pronged rake into and on to the top of the charging hole. A second man stands in line with the opening, and as the material is delivered on to it he pushes it down the incline on to the drying hearth, and continues doing so until the hearth is completely covered. The quantity usually put on at one charge varies from one-third to one-half a cartload, or from 20 cubic feet to 30 cubic feet. From the drying hearth the material is drawn down on the bars as required by the fireman, who stands at a lower level and in front of the furnace. He first clears his fire by pulling the clinker out, spreads the burning material evenly over the fire bars, and then draws down a fresh supply of the partially-dried material from the drying hearth. He usually finishes up by running his bar through the fire, so as to leave as free a passage for the air as possible."

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[1] This apparatus will be described in detail later.

[2] "Report on Dust Destructors," by the Medical Officer and Engineer (London County Council, May, 1893).

[3] Pamphlet on "The Disposal of Town's Refuse," by H. Percy Boulnois, M. Inst. C.E., City Engineer, Liverpool.

Too much refuse should not be drawn down at once, or the fire will become dead and blackened. Thin layers may be raked down at intervals of about 20 minutes, but the fires should be undisturbed for at least half an hour before clinkering. The fire on the bars (which should always be kept covered) should not be more than about 9in. thick, which is sufficient to secure a clear fire.

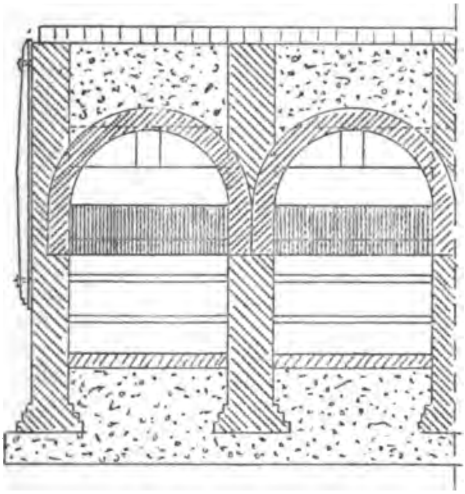

Fig. 6—Fryer's Destructor—Cross Section at A B, Fig. 5.

"The clinker falls into a barrow provided for the purpose or upon the ground in front of the furnace, where it is cooled by having water from a hose sprinkled upon it. The fine ash drops through the bars into the dust hearth, and it is found that the material in passing through the furnace is reduced to about 25 per cent. of its weight. This residue consists partly of fine ash and partly of clinker, in varying proportions according to the character of the material which has been consumed. Whilst the combustion is proceeding, the hot gases from the furnace or cells escape over the bridge into a central flue

6ft. high by 10ft. 4in. wide. This is arranged to prevent too great a velocity from carrying pieces of paper and other unconsumed material to the chimney, and also to allow of the deposit of dust within the flue."

In connection with the Fryer furnace as installed at Ealing, Mr. C. Jones, M. Inst. C.E., has introduced an automatic means of reducing he admission of cold air into the flues, &c., during the processes of eeding and clinkering. "This is done by means of a cast iron hinged door, over the opening entering the dust chamber, attached by a chain to the furnace door, and is so arranged that when the furnace door is open the entrance to the dust chamber has about four-fifths of its area closed; and when the furnace door is shut the flue door is open. This arrangement, being entirely automatic, is quite independent of the attention of the stokers."[1] Also, to reduce the inconvenience of the blowing about of fine dust, a concave water pit is introduced under the fire-bars and into which the ash drops, from whence it is removed in a damp state.

Mr. Stevenson Macadam, Ph.D., F.I.C., &c., as a result of his observations upon this type of destructor, says,[2] there being no forced draught and the supply of air to the cells being entirely dependent upon the suction induced by the chimney shaft, the "general result of working this destructor is that the heats are not sufficient for fully dealing with the combustion of the refuse. There is a tendency for foul-smelling gases to pass away unconsumed; for the cinder stage to be only a dull-red heat, and for the clinkering of the residue to be imperfect. I have seen the stuff dragged out of this destructor in an inflaming condition, and the cinder and clinker still glowing and burning, and evolving organic and sulphur gases most abundantly, rendering the atmosphere quite suffocating and nauseous, whilst the fine dust was being blown about all around and over into the neighbouring properties.

"The imperfectly burned gases leaving the Fryer cell, and going by the main flue to the chimney, are supposed to be consumed in the main flue, but unless the temperature there is a full red heat—about 1500 deg. Fah.—these gases cannot be properly burned there. As I have often seen the main flue at a black-red heat, not above 1000 deg. Fah., it was impossible that the organic gases could be rendered innocuous. The deficiency has apparently been admitted at several stations by the construction in the main flue, between the cells and the chimney, of a '*cremator*' where coke is being burned, and the gases travel over the bed of red-hot coke, and are there consumed. In this way the admittedly imperfect combustion of the refuse products in the cells is met by the use of a cremator, which requires extra labour, and involves additional cost in fuel."

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[1] "Refuse Destructors," by C. Jones, M. Inst. C.E. (1894.)

[2] See *Journal of the Society of Chemical Industry*, March 31st, 1896, No. 3, vol. xv.

WHILEY'S DESTRUCTOR.

This machine, shown in section in Fig. 7, is the patent[1] of Mr. Henry Whiley, the superintendent of the Scavenging Department of the Manchester Corporation, and is designed primarily with a view to labour saving. The arrangement differs from others in that there is no drying hearth, the refuse falling directly through hoppers to the furnace bars. A trough or hopper is provided at the back, into which the carts tip direct. A spout or tube is arranged, through which the refuse falls on to movable eccentric grate bars, similar to Vicar's

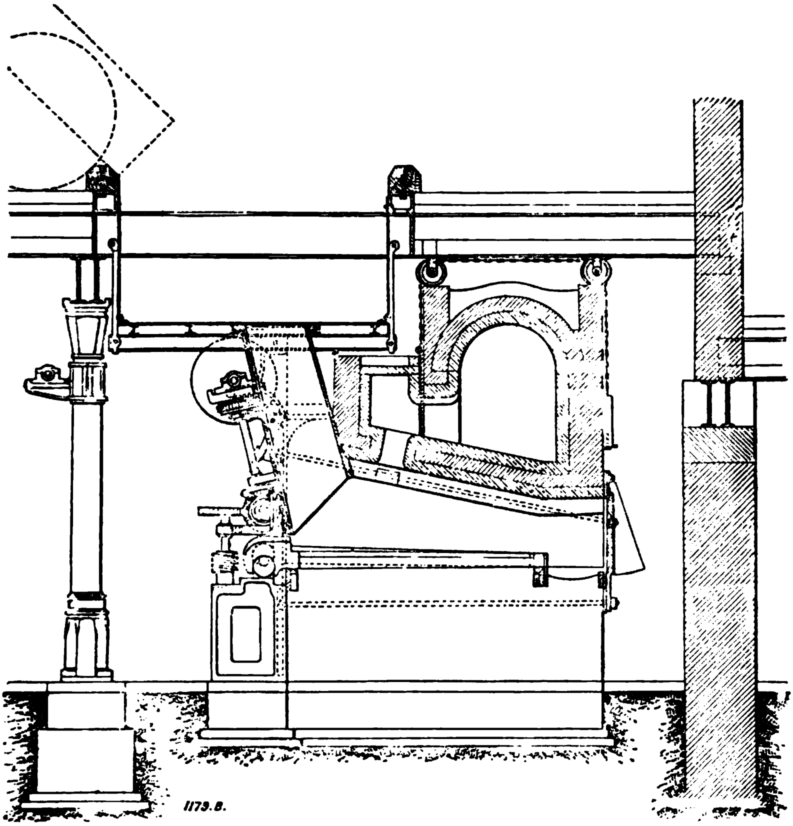

Fig. 7—Section of Whiley's Destructor.

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[1] Patent No. 8271, A.D. 1891.

patent grate bars. These bars automatically traverse the refuse forward in the furnace, and finally push it against a flap door, which opens and allows it to fall out. The important difference between this furnace and others, therefore, is its automatic action, which aims at the reduction of manual labour to a minimum—the cells being fed, stoked, and clinkered automatically as above described.

A means of changing the speed of the bars from time to time is provided by friction gearing, in which the driven wheel running on the face of the driving disc, can be moved nearer to or further from the centre of the disc, which revolves at a constant speed. Some trouble has been experienced from the refuse sticking in the hopper, but no doubt that will be overcome. A more serious drawback to the system is that the grate bars have so much motion that they would let fine refuse drop through unburnt, and are therefore only suitable for places where, as at Manchester, they *screen* all the refuse, or at least select it. Exception may be taken to the mode of pushing out the clinker, as it causes the door to be continually flapping so that it fans cold air into the furnace. At the same time it is only fair to say that with screened Manchester refuse a very fair temperature, said to be about 1000 deg. Fah., is maintained, and the amount burnt is claimed to be ten tons per cell per day. Forced draught is employed by means of a Roots' blower.

It will be noticed from the figure that the outlet into the main flue for the products of combustion is close to the shoot for the crude refuse—an arrangement which facilitates the escape of the objectionable empyreumatic[1] vapours unless the heat of the flues can be maintained at a temperature sufficient to effect their decomposition and render them innocuous.[2]

The Manchester Corporation have laid down a large installation of this form of furnace after having given it an extended trial.

HORSFALL'S DESTRUCTOR.

The Horsfall refuse furnace[3] is a "high temperature" destructor, adopted, either in whole or in part, at Oldham, Leeds, Bradford, Heckmondwike, Nottingham, Salford, Blackpool, Blaby, Calcutta, Berlin, Hamburg, Edinburgh, Norwich, and Ashton-under-Lyne. It will be seen from the section (Fig. 8) that, although the general features of Fryer's destructor are retained, the details of the furnace differ from those previously described. This is particularly noticeable in regard to the arrangement and position of the outlets for the products of combustion, and in the introduction of a blast flue which forces air into a closed ashpit. Speaking generally, the destructor consists of a furnace somewhat similar in dimensions and shape to Fryer's, with

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[1] *Empyreumatic* = pertaining to the peculiar smell and taste arising from products of decomposition of animal or vegetable substances when burnt in close vessels.

[2] It has been ascertained that a temperature of about 1250 deg. is required for this.

[3] Patent No. 8909 (1887); No. 14,709 (1888); and No. 22,581 (1891).

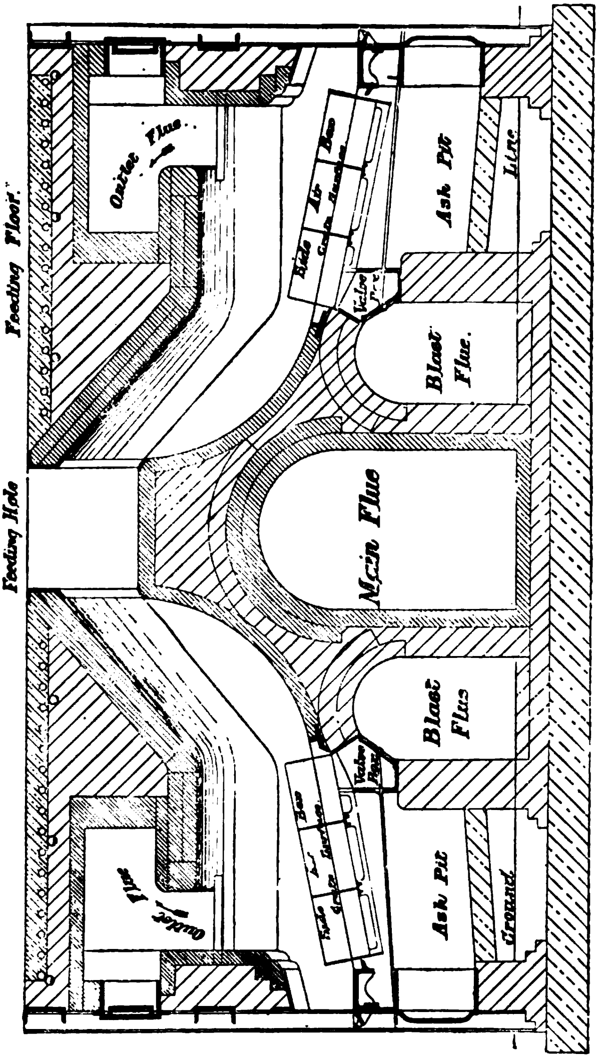

Fig. 8.—Horsfall's Modern Type Destructor.

sloping drying floor and grates, bricked walls protected by cast iron side plates, perforated fire-brick arched roof, side flues, and an enclosed ashpit. The grate, which is composed of mechanical selfclinkering grate bars, is a little over 5ft. square, and at the back of this in the older forms is the drying floor of about 20 square feet in

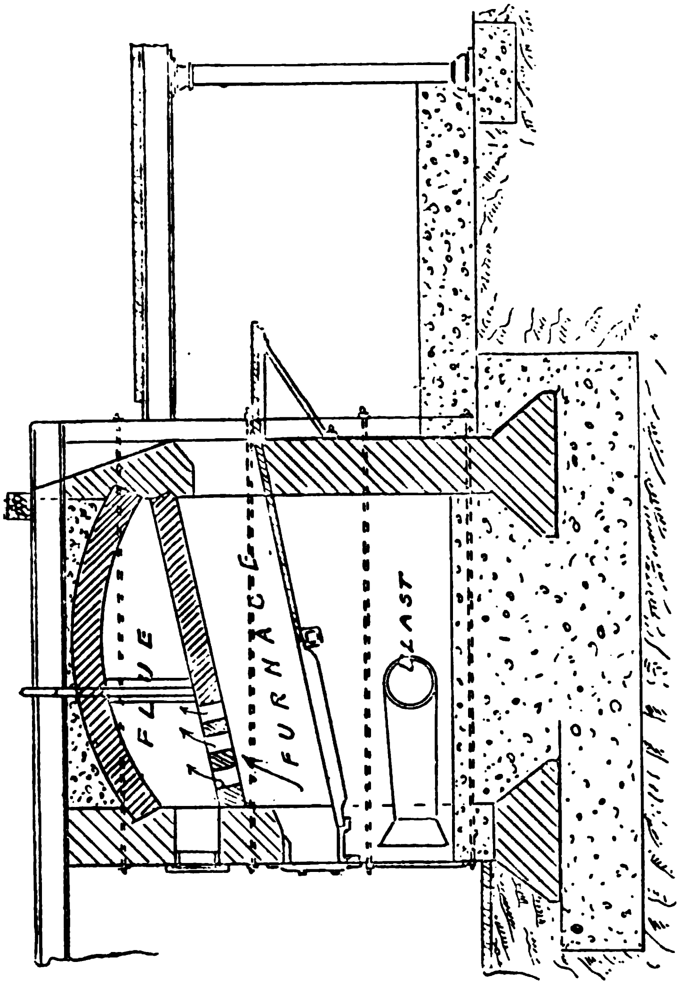

Fig. 9.—Section of Horsfall's Destructor as originally Designed.

area, which, in Horsfall's "improved design," is replaced by a "patent self-feeding apparatus"[1] worked by eccentric gear.

The accompanying diagram — Fig. 9 — illustrates in section the destructor as originally designed by Mr. W. Horsfall, of Leeds, and a destructor of this description is in use at Oldham. The charging opening is situated in the back wall of the furnace, through which the refuse is thrown and distributed as required over the fire-grate and drying hearth.

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[1] Horsfall's Patent Self-feeding Apparatus (patent No. 20,207, 1892).

Another arrangement of this furnace is shown in Fig. 10.

The *steam jet*, which plays an important part in the Horsfall furnace, forces air into the closed ashpit by means of surface friction at a pressure equal to ¼in. of water. This steam, in passing through the glowing carbonaceous cinders, is said to have a "water gas" effect; it "becomes broken up and yields two highly combustible gases, viz., hydrogen and carbonic oxide, and such being afterwards burned in the atmosphere of the cells and in the service and main flues, most materially assist in raising the temperature and in consuming the noxious-smelling gases evolved from the fresh or non-charred town refuse, and aiding in these being changed into innocuous and non-smelling gases."[1] "It is not *claimed* that there is any actual direct gain of heat from the formation and subsequent decomposition of the water gas, but that the action has the effect of carrying the combustion onwards to a further point in the furnace than it would otherwise reach, thus consuming smoke and other combustibles, which would otherwise escape."[2]

As to the special feature in this furnace in the arrangement of the *flues and flue openings*, these, instead of being at the back, as in Fryer's furnace (in which the gases from the drying refuse pass away straight into the main flue) are placed in the front of the reverberatory arch, over the hottest part of the fire. Thus the gases given off by the drying refuse at the back have to pass over the hottest part of the fire (at a temperature claimed to be equal to 2000 deg. Fah.), and through apertures in a red-hot reverberatory arch, before they can escape. The flues pass along over the top of the reverberatory arch, and then down through cavities in the side walls to the main flue underneath. The furnace is therefore practically surrounded with hot gases, which have the effect of drying the green refuse.

In Horsfall's "improved design" a longitudinal *trough or hopper* is provided at the back, into which the carts tip direct; but instead of a shoot being provided, as in Mr. Whiley's, to convey the refuse from the hopper to the furnace, the hopper is brought right down to the grate bars, and the opening at the back is made the full width and height of the furnace.

The *grate bars* in the improved furnace are Settle's patent,[3] and are of the rocking type without, it is stated, either excessive motion or wide spaces, those bars on to which the refuse first falls being dummies, *i.e.*, without air spaces. The motion is imparted by a

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[1] *Journal of the Society of Chemical Industry*, March 31st, 1896.

[2] *Health News*, July, 1895.

[3] Patent No. 15,482 (1885).

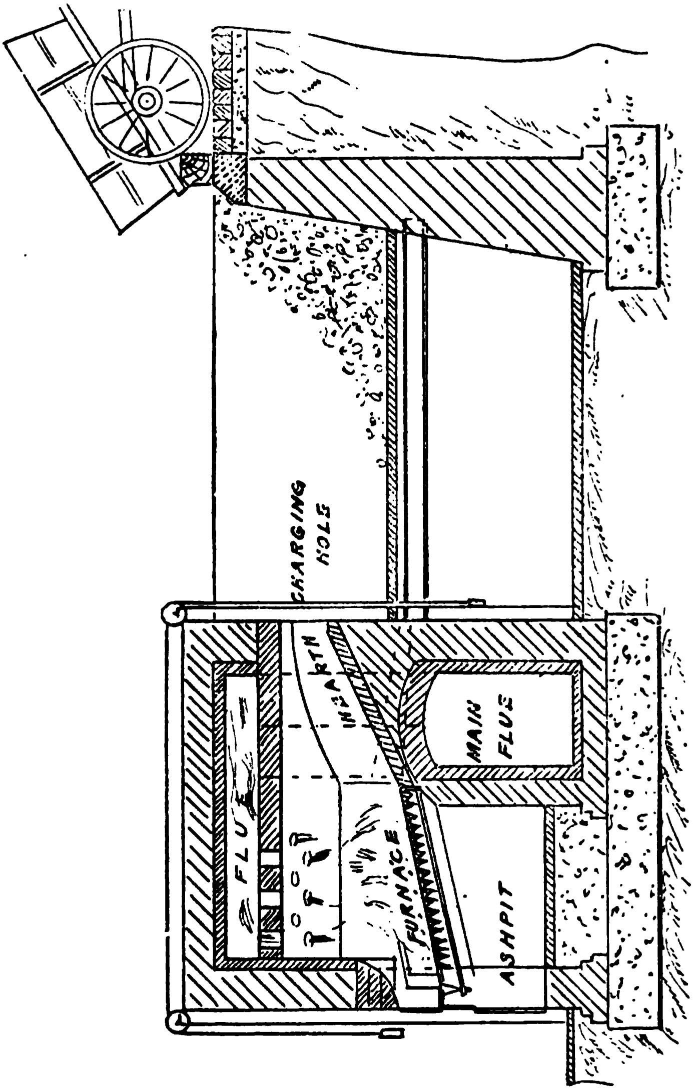

Fig. 10.—Horsfall's Destructor.

small engine, the speed of which can be varied as desired. The *grate surface* proper is 28 square feet in area in each cell. The refuse is gradually moved forwards by a wave-like motion, and deposited in the form of clinker on the wide "dead-plate," where it remains until the attendant comes along to remove it. Thus, it is claimed, the continual admission of cold air to the furnace is avoided, and also less labour is required in raking the clinker off the dead-plate than in shovelling it up off the ground, while all handling of the refuse is obviated until after it has been reduced to clinker. With the use of these bars, it is stated that an output of nine tons per cell per day has been obtained.

There is a separate mattress chamber provided in connection with the main flue, so that large articles can be put into it whole and speedily destroyed.

In the working of the Horsfall destructor, some difficulty is said to arise "owing to the closing up of the comparatively small escape openings leading into the escape service flue, which is due to partial fusion of the brickwork at the high temperature and the adhesion of dust particles to the sides of the openings. The result is the reduction of the openings and draught, and the lessening of the power of the destructor, until the apparatus has been thrown out of work for repairs. Even when working properly, each cell is independent of every other cell, and if any heavy charge of green stuff be thrown in, the temperature of the cell may become materially lowered, so as to admit of foul-smelling gases passing away unconsumed for a time."[1]

The several small escape openings in the reverberatory arch above mentioned are now replaced by the larger opening shown in Fig. 8, which should remove the difficulty referred to.

At Oldham a series of experiments carried out by Mr. Watson showed that the average temperature of the mattress chamber through which the hot gases pass on their way to the boiler was found to be 2019 deg. Fah., the minimum being 1654 deg. Fah., and the maximum 2346 deg. Fah. The above results are confirmed by the melting of three pieces of cast iron, of which the melting point was not less than 2100 deg. Fah., in one of the fires.

For taking the temperatures, the following apparatus on the principle of the "*method of mixtures*"[2] was used. An ordinary iron bucket was cased all over with about 2in. of slag wool or silicate cotton, the cover for the top being movable. A thermometer was hung over the side of the bucket, dipping into about two gallons of water, less or more, weighed for each experiment. Pieces of wrought iron from 4½ lb. to 5½ lb. weight were used, and it was found that the loss of weight by oxidation was negligible even for several successive experiments with the same piece. The loss of heat by radiation from the bucket was also negligible, being at 120 deg. Fah., only 1 deg. in 15 minutes; whereas the maximum temperature of the water, after the hot iron was put into it, was reached in less than five minutes. The method of using the instrument, as is well known, is to place a piece of metal (iron in this case, whose specific heat was taken at 1255) of known weight and specific gravity in the gases whose temperature is to be measured, and, when it has had time to reach the same temperature as the gases, to withdraw it and quickly place it in water of a known weight. The amount by which the temperature rises is a measure of the temperature of the iron before being placed in it.

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[1] *Journal of the Society of Chemical Industry*, March 31st, 1896.

[2] *Vide* paper by Professor W. C. Roberts-Austen, C.B., F.R.S. "Proceedings' Inst. Civil Engineers, vol. cx., page 152.

The temperature of the gases as they escaped from the boiler flues was also measured, and found to be something over 855 deg. Fah.

At Oldham steam is generated by the surplus heat in a Lancashire boiler, and 15-indicated horse-power is said to be obtained from each cell. The power thus generated is utilised in working two mortar mills, to supply power to the horses and provender department and a portion of the electric lighting station, and to produce the forced draught through the furnaces. Each furnace, it is stated, consumes over 8 tons per 24 hours as an average as shown by actual weighing, and as much as 8 tons 16 cwt.[1] per cell per 24 hours has been consumed. The residuum (including clinker and fine ash) of the bulk dealt with is given at 33 per cent. There is no demand for the clinker and ashes as such, but there is said to be a "ready sale for the mortar produced from the clinkers at 5s. per ton; also, successful experiments have been made in converting the clinker into paving blocks."[2]

Mr. C. Estcourt, F.C.S., F.I.C., Public Analyst to the City of Manchester, having analysed samples of clinker and gases resulting from the burning of ashbin refuse, garbage, &c., taken by him during the ordinary course of working at the Oldham destructor, reported[3] the results as extremely satisfactory, showing what a powerful effect the steam draught has upon the combustion. He states that "the carbonic acid without steam on is only 2 per cent., while with steam half on it is 9 per cent., and with steam full on it is 14·5 per cent., proving that the steam draught has the effect of getting full value out of the air that is used. The clinker is so burned that practically there is nothing combustible left therein; it may be tipped in a heap when hot from the furnace without fear of further combustion taking place. Further, no nuisance could arise from a heap of such clinker, either hot or cold. The analyses of the gases taken from the destructor furnace and the flues show that the combustion is practically perfect. No malodorous vapours can possibly escape. This is largely attributable to the action of the steam jet forced-draught apparatus, combined with the other arrangements of the furnace which ensure that only the proper quantity of air is admitted to the furnace. The steam, in passing through the incandescent fuel on the grate, is decomposed in such a manner as to assist in the formation of water-gas. The gases passing from the chimney are remarkably free from dust. The waste gases could not possibly cause a nuisance, or any injury to vegetation in the neighbourhood of the destructor, and in my (Mr. Estcourt's) opinion there is no necessity for a chimney more than 50ft. high to carry them off. The gases are completely cremated, the furnace being designed on thoroughly scientific principles."

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[1] *Vide The Surveyor*, April 2nd, 1897.

[2] *Oldham Evening Chronicle*, May 14th, 1896.

[3] March 27th, 1896.

The analysis of gases taken from the furnaces burning with full steam on is as follows:—

	Per cent.
Carbonic and sulphurous acids	14·6
Oxygen	5·4
Nitrogen	80·0
	100·0

The Horsfall Furnace Syndicate, Ltd., also have a smaller type of this destructor, styled the "*Hospital Destructor*," which is stated to be capable of destroying about two or three tons of the most offensive material in a 12-hour working day. The furnace is used for rendering innocuous infected bedding, clothing, excreta, or any other offensive or dangerous material as garbage and refuse. A destructor of this kind has been supplied to the Joint Hospital Committee of the Blaby and Wigston Isolation Hospital.

HEALEY'S DESTRUCTOR.

A distinguishing feature in connection with this furnace,[1] one form of which is shown in Fig. 11, is the arrangement of flues whereby the gases from one furnace have to pass over the bright fire of another in a more forward state of combustion before escaping. The furnaces are worked in pairs, and the gases alternately made to pass from one to the other by means of dampers. The provision of a movable drying floor over the furnace is also made, upon which the charge is allowed to rest until it is thoroughly dried. The floor is then allowed to fall and drop it on to the grate.

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[1] Mr. Healey has obtained numerous patents for destructor furnaces and arrangements connected therewith. The following may be mentioned for reference :—No. 2369 (1880); No. 5203 (1882); No. 10,035 (1884); No. 7708 (1885); No. 9842 (1886); No. 177 (1888); No. 1005 (1892); No. 8249 (1892); No. 12,990 (1892); No. 18,398 (1892); Nos. 6688 and 13,105 (1893); No. 12,179 (1894); and No. 14,598 (1896).

The refuse is fed on to forward motion fire-bars, and in one form of this furnace the bars have also a slow wave-like motion imparted to them by means of a cam action worked by a special and simple

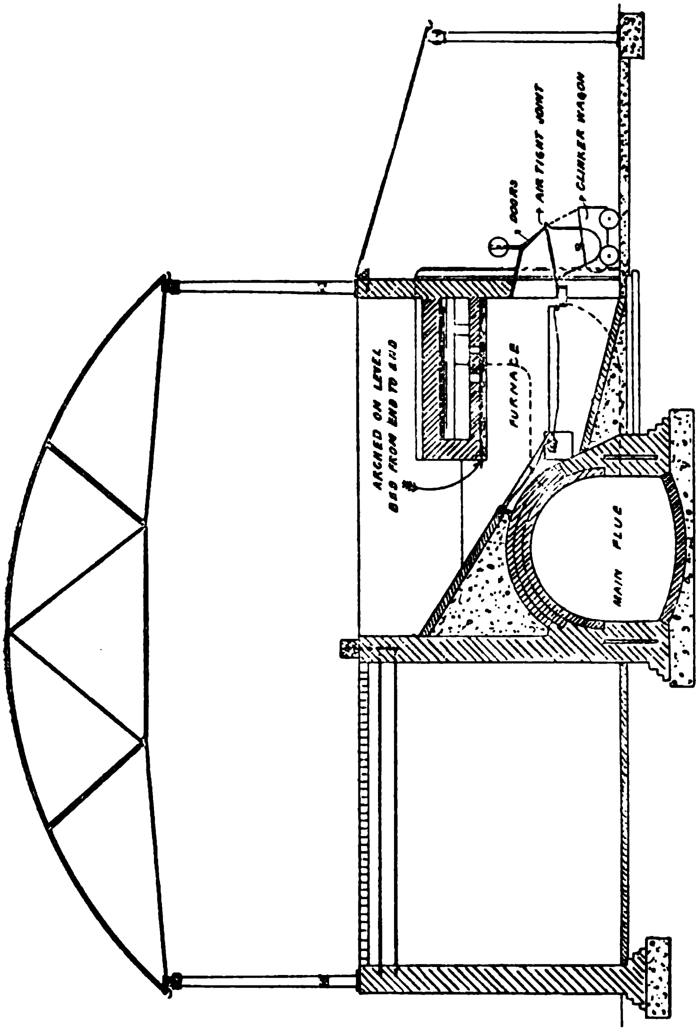

Fig. 11.—Section of one form of Healey's Destructor.

steam or water motor, thus slowly moving the burning refuse towards the furnace doors, where it can be received into an iron trolley or barrow fixed to the furnace door, so that no fumes or heat can escape.

Over the furnace is a reverberatory arch provided with openings communicating with a flue, which itself joins the main flue under the back of the furnace; the communicating flue being constructed in the thickness of the division walls separating the cells. A forced blast is also provided, if thought necessary, to increase the combustion.

A furnace called Fryer's and Healey's destructor was erected at Bradford, and in a paper read by Mr. C. Jones in 1887, at a meeting of Municipal Engineers at Leicester it is referred to in the following terms:—"The arches and furnaces were like Fryer's, and, following in the steps of previous inventors, he (Mr. Healey) attempted to purify the gases. The main arch was constructed hollow over the top and the gases made to pass at the back of each cell down the sides and over the arches, and the high temperature of the arches and flues were to have destroyed the offensive gases." The fumes and smoke of the Southfield-lane Destructor, Bradford, are now passed through a "Fume Cremator."

Mr. B. D. Healey, in 1894, patented a new type of furnace[1] with boiler, and has very recently taken out a further patent for "Improvements in refuse furnaces and steam boilers, and setting boilers in connection therewith."[2] These latter improvements relate to the type of furnace and boiler referred to, and are illustrated in Fig. 12, of which the following is the description:—

Below the ashpit of the furnace is a tunnel[3] for wagons, which receive the fine ashes from the fire-grate. At the back of the ashpit is the blast flue, in which is the main shaft with excentrics for driving the cams of mechanical grates when such are used.

The furnace arch has two sets of ports for passing the gases into the flue, which collects the gases from several furnaces. Either the dampers of the front ports or of the back ports may be fully open, or each may be partly open to suit the requirements of the furnace.

In the arch of the flue are openings through which the heated gases pass to the water-tube boilers, which are set over the furnaces and clinkering floor, or at the ends of a rank of furnaces, as may be most convenient to users.

The heated gases pass over a bridge, and downwards to the flue outlets, which are connected to the main chimney flue, and the velocity of the current passing thereto is regulated by a damper in each outlet.

The boiler may have one water drum at each end, but it is preferable to have sectional headers which take two tiers of water tubes each, as shown in the accompanying figure. The ascension pipes pass upwards to about 3in. above the water level of the steam drum, and the downflow or syphon limb tubes start about 3in. below the water level of the steam drum.

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[1] Patent No. 12,179, A.D. 1894.

[2] Specification patent No. 14,598, A D. 1896.

[3] Tunnel not shown in illustration.

Instead of making the downflow tubes as described above, a dam may be put in water space of steam drum to keep back the mud and deposit, and instead of the ascension pipes extending to above the water level of steam drum, another dam may be put to about 3in. above the water level, and at such distance from the front end of the steam drum as will allow of the ascension pipes delivering their water

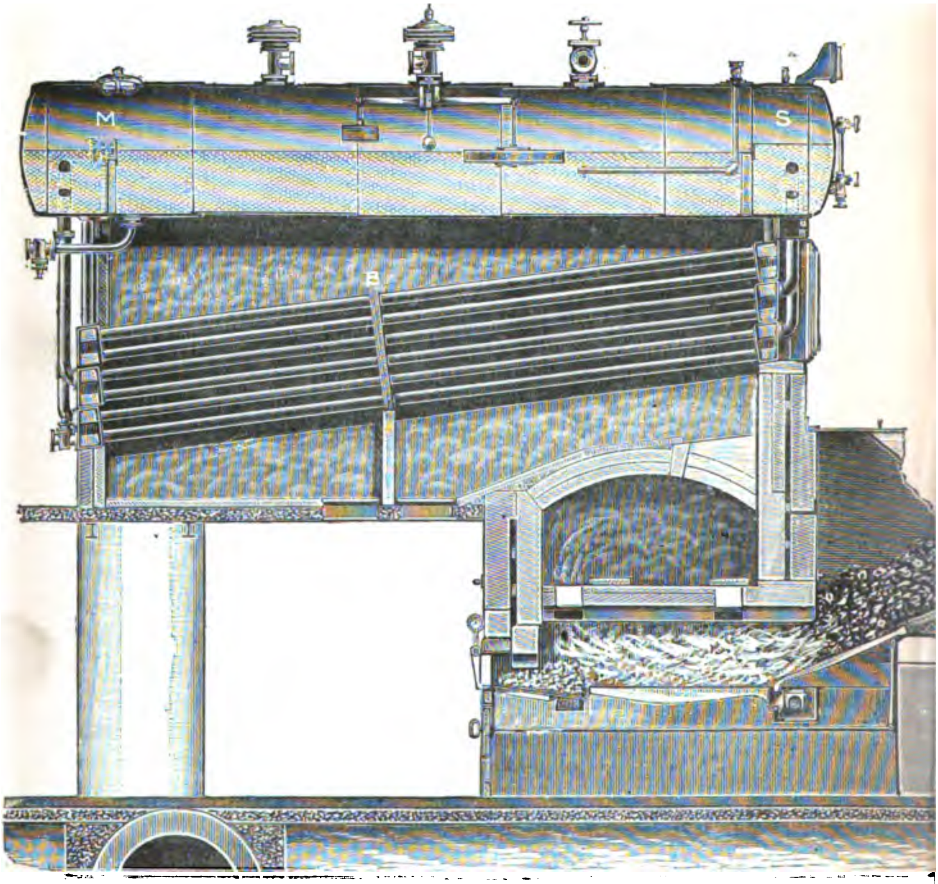

Fig. 12.—Healey's Refuse Furnace, showing boiler setting.

and steam into the separator, which is formed by the latter-named dam.

The upper header has two connecting tubes for downflow of water from the steam drum, and the middle and lower headers have two ∩ connections each, or they may have two separate connections each to the steam drum, arranged in a similar way to those at the front of headers. All the tubes connecting the middle and lower headers with water space of the steam drum are provided with two universal joints for security and handiness of fixing.

The headers are by preference all made of the section indicated in Fig. 12 for front headers, which form a vertical face when set up as shown, but they may also be of the rectangular form as intended for back headers. The usual pockets on the steam drum for receiving the tubes which connect with the headers are not required, but in place thereof single or double seats are attached to the drum and the tubes are expanded into them.

The inclination of the steam-generating tubes between the lower headers and the upper headers does not require to be greater than 1 in 8, and should not be less than 1 in 12.

There is a greater number of tubes in the width of the setting than there is in the height, and this system is adopted whether the boiler is made larger or smaller than the one illustrated, so that in every case a maximum area of flue space is obtained, and a minimum rate of velocity of the gases without retarding the induced currents at the furnaces, and the latter may be worked with or without forced blast, or alternately with and without.

The charging entrance of the furnace springs at the same level as the furnace roof, and the crown of the arching over this entrance and furnace is finished evenly and level from end to end. The entrances for clearing out the dust from the boiler chambers are indicated in the figure. When a furnace is shut off for repairs, suitable close-fitting iron covers are laid over the gap in the ashpit bottom.

When the boilers, as shown and described, are used for solid fuel firing the heated gases pass up and down twice before reaching the outlet flues. In every case the walls of the boiler setting are provided with the usual dust-cleaning slots and doors for steam jets to operate in.

The novel points claimed by Mr. Healey in connection with the above invention, are :—

1. Constructing refuse furnaces with arches over same, having a level line of springers, and with two sets of outlet ports, as shown.

2. Constructing such furnaces with a tunnel for ash wagons, large blast flue, and a collecting and distributing flue for heated gases.

3. Setting water-tube boilers over such furnaces, or at the ends of

ranks of furnaces in the manner shown, or any mere modification thereof.

4. Building water-tube boilers with a greater number of tubes in the width than in the height of the setting.

5. The method of forming the water headers at the ends of the generating tubes of the boilers.

6. The method of connecting the ascension and downflow tubes to the steam drum and water headers.

7. Forming dams in the steam drum or projecting the ascension and downflow tubes thereinto.

8. The system of catching the mud and deposit by dams or their equivalent projecting tubes in the steam drum.

"ACME" DESTRUCTOR.

The "Acme" refuse destructor[1] is the patent of Messrs. Hart and Royle, of Stretford, Manchester. Its general arrangement differs materially from those previously described, as will be observed from the accompanying Figs. 13 and 14. The working of this destructor is as follows:—The material to be burnt being placed in the hopper A gradually falls into the furnace B on the sloping bars, and after loss of its combustible matter, slides down into the ashpit I, from whence it can be removed at convenient intervals by means of a proper shovel, either at K or L. As the ashes, clinker, or purified refuse is removed, a fresh portion follows down the inclined bars, the place of which is immediately taken up by another portion of raw material descending from the hopper, this process proceeding continuously, or at such rate as material is found to emerge at K or L in a sufficiently burned condition.

At B is a new arrangement of furnace bars in the form of a step-bar grate, set at an angle of about 45 deg., with large spaces for the admission of air to increase the draught, so that no blowers for a forced draught are used by the patentees.

The feeding in of the material is said to be almost as gradual as though rocking bars were employed. The action of the hanging bridge, writes Mr. Royle,[2] is also to be noted, "any vapour evolved from the raw material is deflected partly over the surface of, and partly actually through, the already incandescent portion, where it also meets the red-hot gases arising from the combustion of the lower portion and becoming ignited, finally passes through the combustion chambers, heating these to such a high temperature that no combustible vapour can escape. As each spadeful is withdrawn it is followed through the whole system by an equal volume of the raw material, the volatile matter from which being thus slowly evolved, has ample time for complete combustion, which cannot be the case where large charges are thrown on at one time. Although designed as a destructor only, it is as capable as any other of being adapted to the generating of steam when the material to be burned contains enough heat-producing material; it equally permits the use of rocking bars, as also the use of a steam or other blower being applied. For the latter purpose it is only necessary to close the front, as is usually done, and fix the necessary blower or fan."

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[1] Patent No. 8732 (1892).

[2] *Vide* paper on "The Acme Refuse Destructor," by H. Royle, A.M.I.C.E., read at the Liverpool Congress of the Sanitary Institute, 1894

The inventors of the "Acme" destructor claim for it that:—

(1) It can be constructed at less first cost than any other.

(2) For efficiency, for ease of working—that is, the feeding with raw and the removal of burnt material—it offers every advantage.

(3) That, from its simplicity and freedom from working parts, it is less liable to get out of order than any other, therefore will neither require expensive skilled labour nor incur frequent stoppages with consequent decrease of working time. Any repairs needed can be done by any ordinary blacksmith or bricklayer.

(4) That it effects complete combustion of all carbonaceous or other organic matter in a systematic manner, all vapours having to pass through red-hot material and highly-heated combustion chambers, thus rendering the escape of noxious gases impossible.

In regard to the capabilities of the "Acme" as a steam producer, and as to the question of utilisation of heat generated by destructors generally, the inventors express the following opinions:—"It is impossible to forecast this amount until experiments have shown what amount is given by them when in actual work, the conditions being so various. To this end we recommend that a boiler should not be put down until this has been ascertained. The amount of combustible matter may be more or less in the refuse of one town or place than another, and therefore the heat generated be more or less; and as a boiler should be proportionable in dimensions to the amount of fuel used, until this is known it is impossible to give accurate dimensions. We are confident that our destructor will give out the full calorific value of the burnable matter in the refuse."

The "Acme" furnace is also claimed to be a "fume cremator" in itself, so that any additional provision in this direction would be superfluous. The furnaces are simple in construction, and have a grate area or fire-bar space of 36 square feet. The cost of the cell, as shown in Fig. 13, is from £65 to £70.

Some furnaces of this type, fitted with "Step Bar Grates," are in use at Messrs. Tennant and Company's Chemical Works, Mill-street, Clayton. At Messrs. Tennant's works a trial has recently been made in the burning of town refuse in two small grates, each 4ft. by 1ft. 6in., *i.e.*, 12 square feet area. In these six loads of refuse were burnt in 33·5 hours, being ·179, or about one-sixth of a load per hour. Unfortunately the loads were not weighed, but assuming the weight

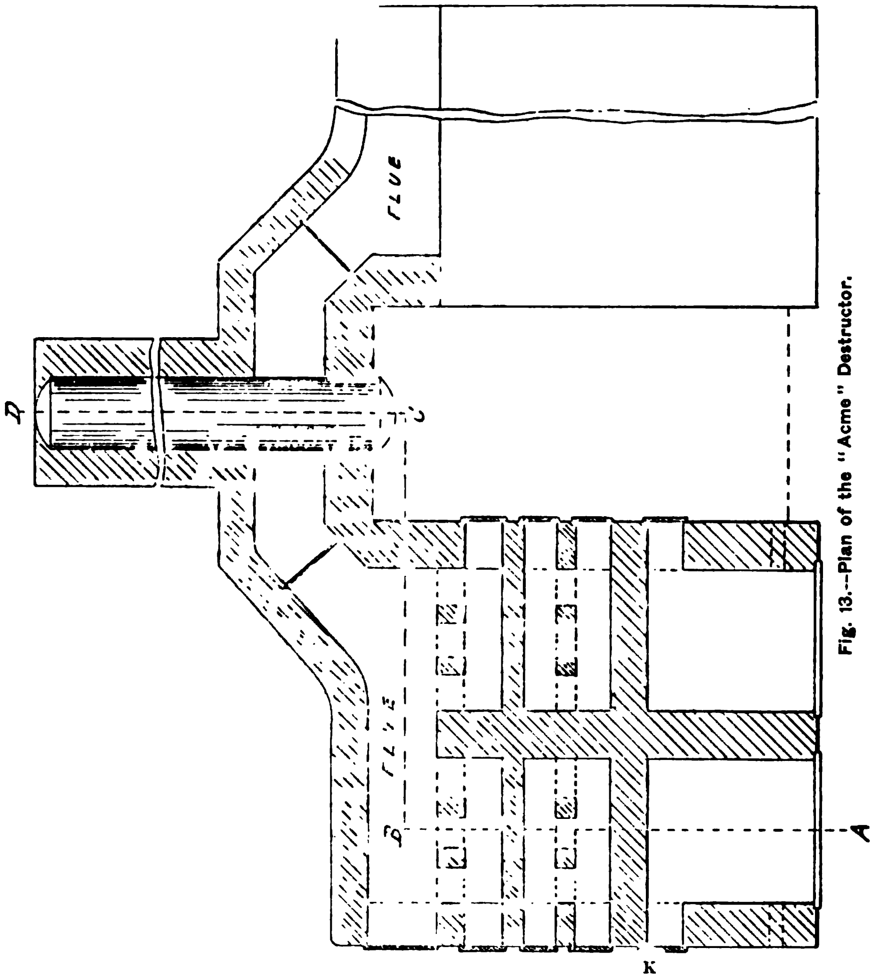

Fig. 13.—Plan of the "Acme" Destructor.

of each at 24 cwt., the consumption was at the rate of $\left(\frac{24}{6}\right)$ 4 cwt. per hour, *i.e.*, $\frac{4 \text{ cwt.}}{12 \text{ sq. ft. grate area}} = \cdot 33$ cwt. per foot grate area per hour. There was no forced draught; the draught, on the contrary, was slight in comparison with that ordinarily obtainable in connection

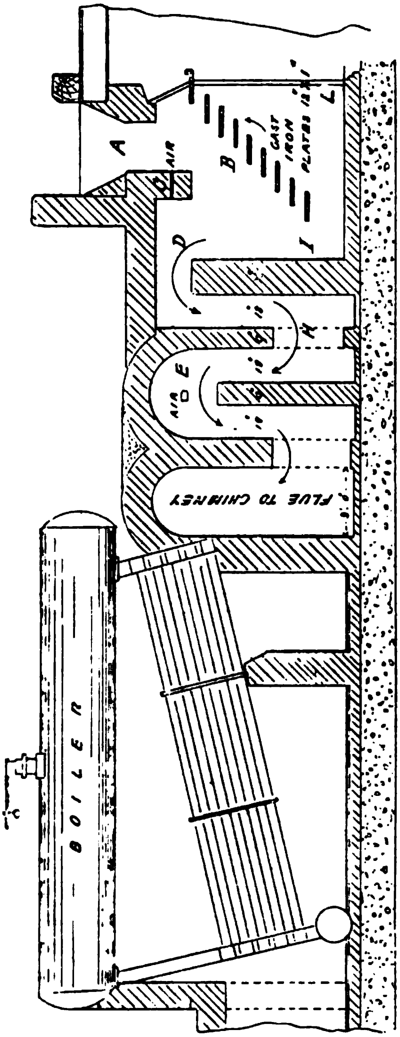

Fig. 14.—The "Acme" Destructor, Section A, B, C, D.

with a tall destructor chimney, and the smallness of the furnaces was unfavourable to the test.

Warner's Destructor.

Warner's[1] patent "Perfectus" destructor (Fig. 15), with its recent improvements, is one of the latest furnaces for burning house refuse, of which some 500 cells are now in use. This destructor is in operation at Hornsey, Bournemouth, Newcastle-on-Tyne, Winchester, Govan, Hyde, Royton, Bath, Southampton, and several other towns. In general arrangement it is very similar to Fryer's, but differs from it in having a special charging arrangement, consisting of a hopper with a movable bottom. A charge is put into the hopper and a plate put over it to prevent the escape of smoke and fumes. A lever is then moved which releases the bottom door and allows the refuse to fall on to the drying hearth. Another important improvement is the provision of dampers to the flues of each furnace, which can be closed during the process of clinkering, and so keep up the heat of the furnace during the operation. Special dust-catching arrangements are also included in thedesign, and sometimes forced draught produced by a powerful fan is applied.

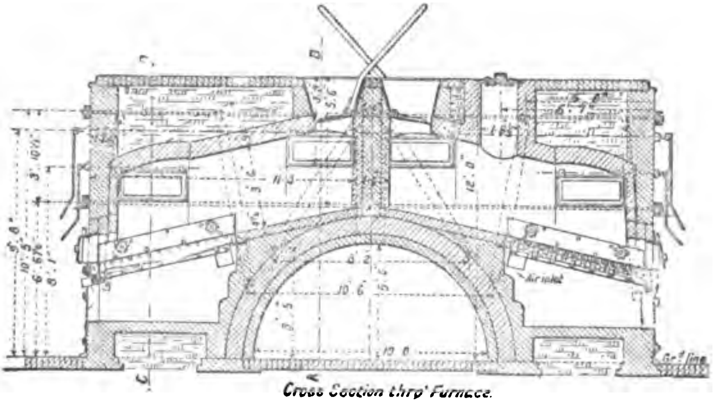

Fig. 15.—Section of Warner's Patent "Perfectus" Destructor.

One of the latest installations of Warner's Destructor is that laid down at Bath. These works have recently been described at some length in *Engineering*.[2] The refuse is tipped into feeding hoppers, which consist of rectangular cast iron boxes. There is a flap door upon an axis at the lower part, the door being controlled by iron levers. When it is required to feed in refuse, the lever is thrown over, and the contents of the hopper fall immediately on the hearth beneath, and the door is at once closed again. It is desirable that when the operation of charging is to be performed the door should be open as short a time as possible, to prevent the admission of cold air into the furnace at the back end, a consequence which leads to the cooling of the gases evolved, and also to paper or light refuse being carried into the flues.

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[1] Patent No. 18,719 (1883).

[2] January 3rd, 1896.

The *furnaces* or *cells* are each 5ft. wide and 11ft. deep. The part where the refuse first falls constitutes a drying hearth, whilst the lower part has *rocking grate bars*, as shown, and here combustion takes places. The furnace doors in front are of the sliding type, and are constructed of cast iron with hollow backs, to allow of the attachment of baffled plates. Holes are made to give a small amount of air, and to provide a cooling effect.

Over the grate and the drying hearth there is turned a reverberatory fire-brick arch which has openings for the exit of gases at the sides, as shown in the figure. These openings are fitted with flap dampers, which are operated by horizontal spindles passing through the brickwork to the front of the furnaces, where they are fitted with levers. In this way each cell may be operated independently of others—a feature which enables each workman to manage his own furnaces independently of the others—and the fires can be thus kept in better condition; besides which it affords a safeguard against dust getting into the chimneys and flues. When the dampers are closed,

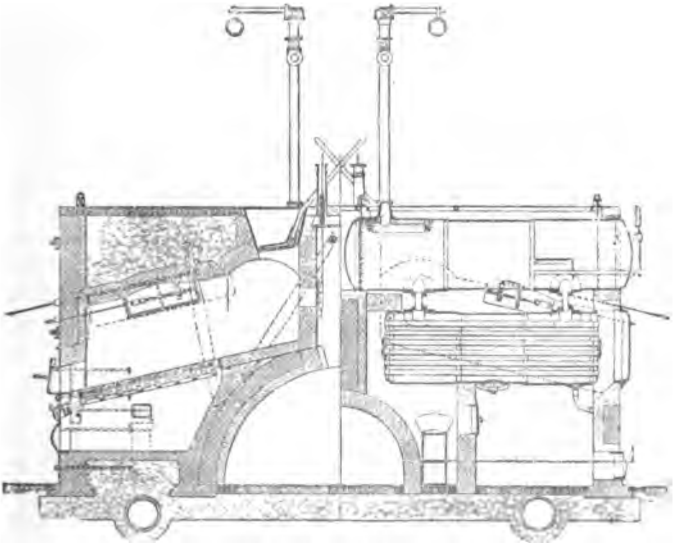

Fig. 16.—Warner's "Perfectus" Destructor with Boiler.

cold air is prevented from passing under the reverberatory arch and into the flues. The heated gases or products of combustion are taken by flues to the boiler-house, where they are used for generating steam.

At Royton four of the Warner cells are in use and are aided by a "cremator" heated by oil. The consumption of refuse here is equal to about five tons per cell per twenty-four hours, but this type of furnace will destroy up to about eight tons, according to the nature of the material. The clinker produced is equal to about 25 per cent. of the refuse.

Fig. 16 shows a recent improvement in arrangement of Warner's furnace, with the view of increasing its steam-raising capabilities. It will be seen that a forced draught has been introduced, and a tubular boiler is shown placed close to the cells instead of at some distance away in the main flue, as at Bath, &c. Mr. Richards, the city surveyor of Sydney, N.S.W., has recently reported favourably upon the furnace for dealing with the refuse of that city. The following extract from the *Sydney Morning Herald*, October 7th, 1897, gives some of the details of the report, and will be of interest in this connection:—The first of a series of reports by the city surveyor of Sydney, on the treatment and destruction of refuse, &c., in Europe was presented at a special meeting of the City Council held in October, 1897. This report is devoted almost wholly to methods employed for destruction of refuse, garbage, &c. Mr. Richards reports to the City Council that on his visit to England he "soon became aware that all England, in fact municipal authorities from all parts of the universe, were seeking to learn what destructor was doing the best work in England." After communicating with and interviewing surveyors and engineers who were regarded as amongst the best authorities in England, with many years' experience in such work, Mr. Richards selected from their advice, coupled with other information, the cities in which the most modern destructors were in use, and in his travels he visited no fewer than forty-five cities and towns. He visited and inquired into works at Manchester, Bury, Oldham, Royton, Cambridge, Hornsey, Southampton, Bournemouth, Eastbourne, Cardiff, Glasgow, Edinburgh, Leeds, St. Luke's, Lambeth, Kensington, Westminster, Cheltenham, Islington, Deptford, Leyton, Salford, Hampstead, Newcastle-upon-Tyne, Nottingham, Sheffield, Rochdale, St. Pancras, Battersea, Birmingham, Liverpool, Govan, Great Yarmouth, Bradford, Bristol, Huddersfield, Hyde, Warrington, Paris, Berlin, Dresden, Leipzic, Winchester, Vienna, and Brussels.

After describing the works in operation at various towns and cities visited by him, Mr. Richards says:—

"The real value of a destructor is that, however clumsy and costly the plan of burning refuse may be, it is at any rate effectual as a means of getting rid rapidly and completely of a readily decomposable and therefore dangerous matter.

With proper destructor power and efficient daily collection of refuse, it should always be possible to get rid of dangerous material within twenty-four hours, before it has time to ferment and develope its peculiar powers. In no other way can this be done with so much certainty or so quickly as by fire. There is also this further advantage, that by so dealing with about one-third of the refuse we render another third saleable, and the remainder harmless. And the cost of this advantage is one shilling per ton on one-third of the refuse—fourpence per ton on the whole. Surely not an extravagant price! The free use of destructors seems to me the most efficient and safest mode at present known of doing this work and doing it effectually, and the Council would be prudent in making themselves safe by adopting it, and the sooner the better. That properly managed they need be no nuisance has been abundantly proved. Wherever they have been put in action prejudice has died out by degrees, and the anticipated disagreeables have not proved realities. That they should be considered of enough importance to be mentioned in comparison with the health of the city is unaccountable."

While in England Mr. Richards called for tenders for the erection of a refuse destructor in Sydney, the installation to consist of a six-cell destructor complete with all machinery and appliances, including clinker breaker and mortar mill. The shaft and primary arrangement to be of sufficient capacity for the further addition of six cells at any time after the erection of the first six that the Sydney Municipal Council may determine. The machinery to comprise one mortar mill, one clinker breaker, one engine, and feed pump for the boiler, large water tank, the shafting, belts and pulleys for driving the various machines, and the steam pipes connecting the engine and pump with the boiler. The tender to include exhaust pipes and drain pipes from the steam cylinders. The contract also to include the supply of all labour, tools, carriage, excavation, and cost of labour for working for six months, necessary to complete the whole of the works to the entire satisfaction of the city surveyor. All materials to be the best of their respective kinds and approved by the city surveyor or other authorised officer of the Sydney Municipal Council. Three tenders were received, namely, those from Beaman and Deas; Goddard, Massey, and Warner; and Manlove and Alliott (Fryer's). Beaman and Deas proposed a six-cell destructor with all fittings, boilers, shafting, in accordance with specifications submitted with all plant necessary for the electric lighting of the buildings at a cost of £9700.

Messrs. Goddard, Massey, and Warner's scheme include six destructor cells complete, all brickwork for cells, buildings, flues, shaft, &c., two tubular boilers, valves, fittings on high-pressure steam engine for driving the mills and general machinery, one donkey-pump for feeding the boilers, vertical engine for driving the fans at such speed as may be necessary, one blowing fan, one tank (1000 gallons), an improved mortar mill for grinding clinker for mortar, one mill for breaking clinker suitable for footways and carriageways, shafting, pulleys, piping and fixing same; chimney shaft, 150ft. high, with capacity for twelve cells; buildings consisting of brickwork and ironwork in the retaining walls, and roof work. Cost of works, £9580; electric lighting, £175; working for six months, £416.

Mr. Richards reported that Goddard, Massey, and Warner's scheme was the most suitable for the city of Sydney.

That firm undertook to pay the same rates of wages for labourers and mechanics as are paid the day labour staff of the City Council, and to engage local labour throughout. They were also prepared to allow the City Council to carry out any of the respective works in the event of the Council so determining, but they reserved to themselves the right of fixing and installing all the patented parts of the plant and appurtenances.

The conclusions arrived at by Mr. Richards were as follows:—That it is necessary in the interests of public comfort and health to at once establish means for the destruction of house refuse by fire. That the best and most suitable means for the treatment of Sydney's refuse is that by Warner's "Perfectus" patent refuse destructor. That for the whole quantity of house refuse collected twenty-four cells would be required. That street sweepings and gully soil may be turned to good account for top-dressing our reserves, parks, &c. That, with a view to the utmost economy, four refuse destructor depôts should be established—say, one Moore Park, South Sydney; one Ultimo, West Sydney; one near the vicinity of Kent-street North; and one at East Sydney, near Rushcutter Bay. That it would be advantageous for the Council to acquire and maintain stock and plant for cartage, not only of refuse, but for all purposes in city works; and that buildings for workshops, stabling, yarding of carts, &c., should be attached to each destructor. This is the custom in all important cities of England, and works very satisfactorily.

THE MELDRUM FURNACE.

The Meldrum patent "Simplex" destructor is a modern apparatus manufactured by Messrs. Meldrum Bros., of Manchester. In this furnace, it is claimed, ordinary town's refuse will give a sufficiently high temperature to utterly decompose all noxious material, nothing but harmless and inoffensive gases passing up the chimney, the solid residue consisting entirely of hard clinker with a little ash. When it is desired to utilise all the available heat for steam-raising a special internally-fired steam generator is employed.

Ordinarily, the furnaces are fed by hand, but hopper feeding may be arranged if required. A forced draught is used in connection with the furnace, but no cremator is considered necessary, owing to the high temperature of the cells.

From the accompanying figures (17 and 18) it will be observed that four grates are placed side by side and separated only by dead plates, the ashpit, however, being divided in four parts, each separately fed with a supply of air under pressure, preferably by steam air blast. The destructor, therefore, is practically a single cell, fed and cleaned in four places at regular intervals, so that an approximately constant temperature may be anticipated.

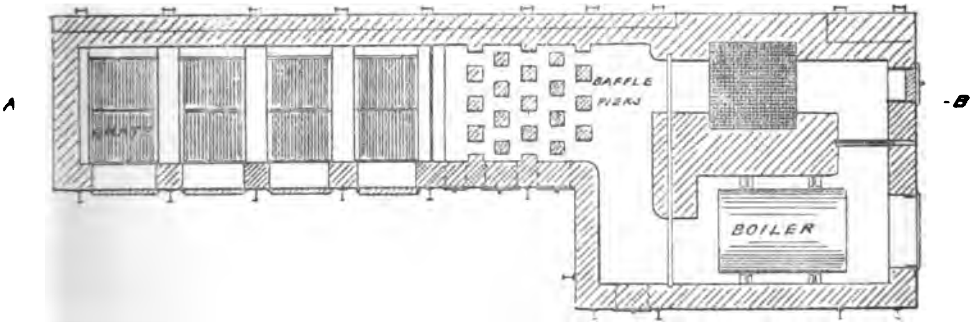

Fig. 17.—"Meldrum" Destructor. Plan.

The escaping gases either pass away from the back of each fire-grate into a common flue leading to boilers or the chimney, or are conveyed sideways over the various grates, and thence over a common fire-bridge towards the boilers or chimney. After passing the fire-bridge it will be seen there are five rows of baffle pillars arranged to divide and break up the current of hot gases; the pillars remain constantly at a bright red or white heat, and take the place, it is claimed, of the cremator furnace commonly used in the older destructor installations. A bye-pass is, of course, provided in order that the furnaces may be used without the boilers. The patentees recommend the four grates be laid down as shown in the accompanying illustrations, but fewer or more may be provided to suit circumstances. One or more of the grates may be disused without interfering with the working of the remaining portion of the destructor.

The main object of the "Meldrum" furnace, which may also be applied to every description of boiler and is now to be found fitted in almost all parts of the world, is to economise the cost of evaporation by the use of the commonest and poorest kinds of fuel, as coal or coke dust, ashpit refuse, &c.

The ashpits are closed by a cast iron plate, fitting air-tight, and provided with an air-tight door for removing the fine ash. Two patent steam jet blowers are provided for each furnace, lying within the ashpit, and fixed to the ashpit front. Steam is supplied to the two blowers from one steam pipe, the air blast being regulated at will by a steam cock or valve. The blowers are the simplest form of jet apparatus made, and use no more steam than necessary to preserve the bars, and, it is said, less than that evaporated from the water bath adopted in some systems for keeping the bars cool. The blowers are constructed to give any required pressure of blast, to 6in. water column and upwards for special circumstances, but, as a rule, no more than 1in. to 1½in. is required. Some of the advantages claimed for this system of forced draught are:—Any kind of fuel, however inferior, can be burnt; no tall chimney is required; evaporative power increased; clinkers are prevented from adhering to the fire-bars; the fire-bars are preserved.

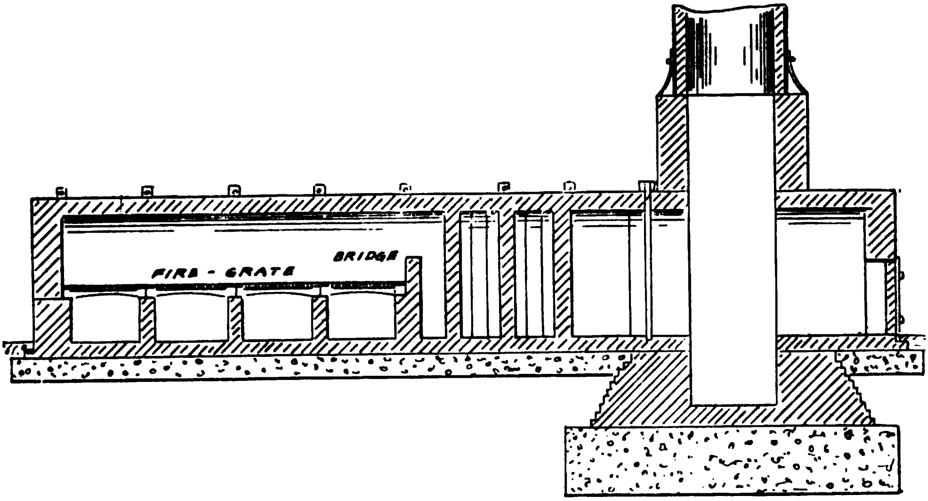

Fig. 18.—"Meldrum" Destructor. Section.

The patent fire-bars (see Fig. 19) are provided with a special locking arrangement to prevent any bars being accidentally lifted when cleaning; this avoids burning, and in consequence the bars, with judicious use, will last for many years. The bars are spaced under ⅛in. apart, so that nothing of value can fall through. The saving of fuel, in the case of ordinary boiler furnaces, from this source alone, is said to more than cover the cost of steam for working the blowers.

At Basingstoke the sewage of the town is being pumped by means of power derived from the burning of town refuse in Meldrum's forced draught furnaces, and on November 17th, 1893, nine hours' pumping took 23 cwt. 2 qr. of refuse to keep up 45 lb. pressure of steam, which lifted 274,000 gallons of sewage 100ft. high.

In regard to the question of the number of "Meldrum" cells required proportionately to any given population, if we take the annual production of house refuse per 1000 inhabitants at 200 tons, then a single "cell," that is a grate 5ft. by 18ft., having four ashpits, and burning at an assumed average rate of 40 lb. per square foot per hour, would consume (90 square feet × 40 lb. × 24 hours) about 38 tons per day of 24 hours, or per year of 300 days = say, 10,000 tons. Consequently, if this rate of consumption be uniform and constant throughout the year, such a cell or destructor should suffice for $\frac{10,000}{200} = 50,000$ people.

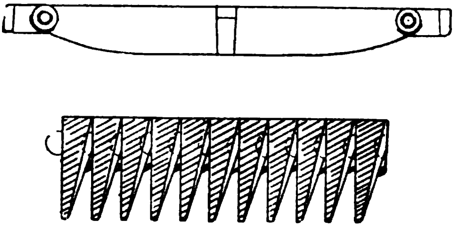

Fig. 19.—The "Meldrum" Fire-bars.

The heat derived in indicated horse-power per cell would, theoretically—assuming a maximum duty of 2 lb. of water evaporated per lb. of refuse consumed — be equal to $\frac{90 \text{ sq. ft.} \times 40 \text{ lb.} \times 2}{20} = 360$ horse-power continuously per cell at 20 lb. steam per 1 horse-power per hour.

A height of chimney shaft of 40ft. is said to be ample for the requirements of the "Meldrum" furnace; and the temperature in the cell if fitted with regenerator may be taken as averaging about 2000 deg. Fah.

A four-cell destructor has been working at Rochdale for some three or four years, and cells are being fitted at Hyde, near Manchester, and at Darwen; also, four of the cells, or rather one four-ashpit destructor has recently been erected, attached to two Lancashire boilers at the sewage-pumping station, Hereford.

In a letter appearing in the *Contract Journal*, of March 17th, 1897, in connection with the recent Cardiff Report on the Disposal of Towns' Refuse, it is observed that Mr. Harpur, Borough Engineer, Cardiff, concludes that town refuse will not make steam beyond a pressure of 70 lb. per square inch; but, it is further stated, Meldrum Brothers are prepared to guarantee to evaporate steam at 180 lb. or 200 lb. pressure, the fuel being unscreened town's refuse.

The actual pressure maintained at Rochdale is given at 110 lb. per square inch. Electrical engineers usually desire a pressure of about 150 lb. to 160 lb., and, it is claimed, a destructor on the "Meldrum" principle would maintain this pressure without difficulty.

In regard to the question of steam, the following evaporative tests will be of interest:—

Evaporative Tests made on a Lancashire boiler, 28ft. by 7ft., flues 2ft. 9in. diameter, fitted with "Meldrum Furnaces" at the *Salford Sewage Works*, Mode Wheel. Fuel used, unscreened ashpit refuse.

Date of test	Feb. 19 and 20, 1895.
Duration of test	14 h. 10 min.
Weight of unscreened ashpit refuse burned	18,704 lb.
Average steam pressure	50·5 lb.
Average temperature of feed-water	42·9 deg. Fah.
Water evaporated during test	36,000 lb.
Refuse burnt per hour	1320 lb.
Water evaporated per hour	2540 lb.
Water evaporated in lbs. per lb. of refuse, actual conditions	1·9 lb.
Water evaporated per lb. of refuse, from and at 212 deg. Fah.	2·28 lb.

Evaporative Test of unscreened ashpit refuse burned in Meldrum furnaces, fitted in front of two Lancashire boilers 30ft. by 8ft., with two flues of 3ft. diameter, at the *Rochdale Sanitary Works*, March 1st, 1895.

Duration of test	6 hours.
Average steam pressure	113 lb.
Average temperature of feed-water	53 deg. Fah.
Total water evaporated	4207 gallons.
Total refuse burned	11·4 tons.
Total residue (clinker)	4·15 tons.
Temperature in combustion chamber at 4 o'clock, tested with Siemens' Pyrometer	1988 deg. Fah.
Ditto, ditto, at 4·30 o'clock after clinkering and feeding	1290 deg. Fah.
Water evaporated per boiler per hour	350 gallons.
Refuse burned per boiler per hour	2128 lb.
Water evaporated per lb. of refuse (actual)	1·64 lb.
Water evaporated per lb. of refuse, from and at 212 deg. Fah.	1·97 lb.
Percentage of clinker to refuse	36 per cent.

Blowers supplied with steam at 55 lb. pressure from separate range of boilers.

Mr. Stevenson Macadam, Ph.D., F.I.C., writing in the *Journal* of the Society of Chemical Industry[1] upon refuse destructors, observes that his inspection of this destructor at full work satisfied him "that an excellent temperature could be got up and maintained in the various grates when all the doors were closed, but the mode of charging the respective grates by hand feeding, with the doors open, led to the entrance of much air into the combination, which must necessarily have a cooling influence on the whole, and lessen the efficiency of this destructor for consuming the smelling gases evolved from the foul garbage, especially when the newly-charged grate is near the chimney end of the combination." It should, however, be noted that after passing the fire-bridge the gases come in contact with the baffle pillars above described, which if maintained at a "bright red or white heat" must have an important effect towards ensuring the perfect combustion of all offensive vapours.

At Rochdale is a destructor of this class, designed by Mr. Brookman, with Meldrum's grates and steam jet blowers. The cost for labour is put down at 10d. per ton. Three men can dispose of ten tons of refuse in ten hours in each of the two cells; this, with wages at 25s. per week per man gives 7½d. per ton for labour at the furnaces —adding to this a proportion of the expenses of supervision, &c., making the cost 10d.

BEAMAN AND DEAS' DESTRUCTOR.

One of the most modern destructors is that of Messrs. Beaman and Deas,[2] which is illustrated in plan and section by the accompanying figures (20 and 21), which show the general arrangement and construction of the furnace. The Beaman and Deas destructor is, at the present time, commanding a large share of attention from Public Authorities throughout the United Kingdom, and installations have already been erected at Warrington, Dewsbury, Leyton, &c., whilst Barry, Bermondsey, Burnley, Colne, Canterbury, Cardiff, Llandudno, Sheffield, Nelson, St. Helens, Stretford, Streatham, and Rotherhithe, are either erecting or have decided upon the erection of this type of furnace.

The material to be burnt is carted up a short incline to the top of a platform, which measures only 8ft. 9in. from the ground level, and is tipped direct into a hopper mouth about 1ft. 6in. square; after passing which it falls down a fire-brick hearth supported on T irons, as shown, and having an inclination with a horizontal line of about 52 deg. At the bottom of this incline the refuse is received upon a fire-grate area 5ft. square, which is fixed level at a height of about 2ft. 9in. above

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[1] March 31st, 1896.

[2] Patents No. 15,593 (1893) and 28,712 (1893).

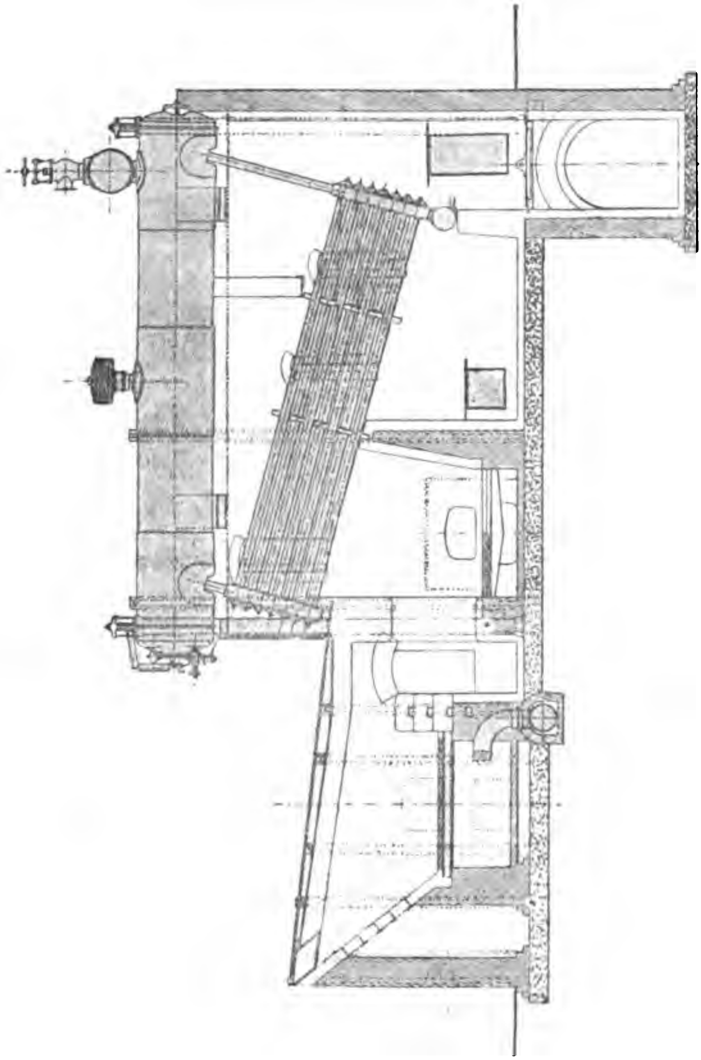

Fig. 20.—Section of Beaman and Deas Destructor.

the floor of the ashpit. The fire-bars are of the ordinary stationary type, these having been found by experience to give the most satisfactory results. They have spaces between them of only $\frac{3}{32}$in., and

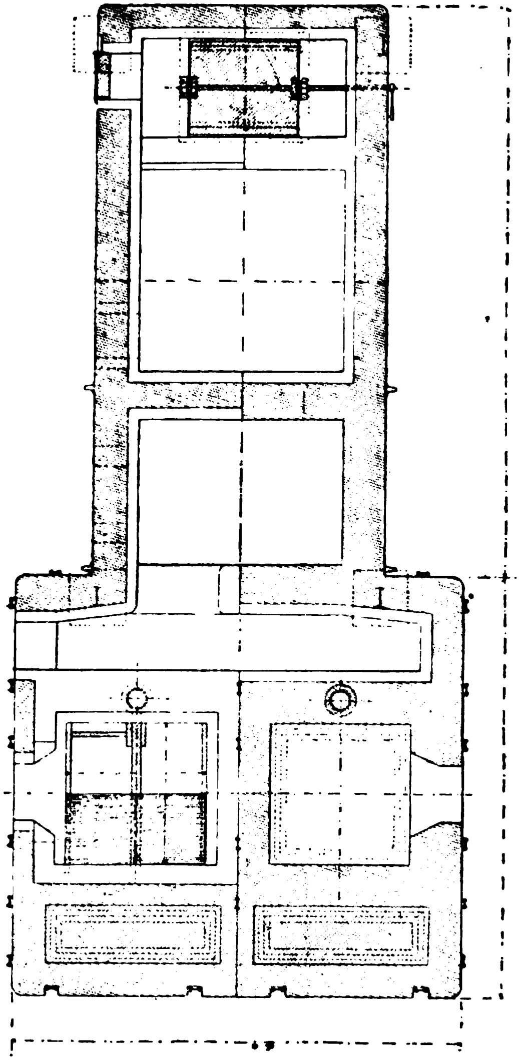

Fig. 21.—Plan of Beaman and Deas Destructor.

the weight of fine ash passing through from a week's work of five days—and burning about 100 tons—only amounts to 8½ cwt. Vertically under the bridge between the furnace and the combustion chamber is an air culvert, on the top of which are the air blast pipes, about 12in. in diam., and which discharge into a hermetically-closed ashpit immediately under the fire-bars. The air is supplied from fans at a pressure of about 2in. of water, and is controlled by means of baffle valves worked by handles on either side of the furnace, handy to the attendant. The forced draught keeps the bars cool, and the wear and tear is found by experience to be very slight.

The fumes from the charge drying on the hearth pass through the fire, directly over the fire-bars and over the fire-bridge. The bridge is perforated longitudinally with air passages, as shown in the figure; these perforations connect with a miniature flue, leading from a grated opening on the face of the brickwork outside. This creates a strong draught, and the air in the course of its passage becomes heated, is discharged near the top of the bridge, and thus meets the fumes passing over into the combustion chamber, and ensures their perfect combustion by means of this auxiliary supply of heated oxygen; the principle of the action being, in fact, somewhat similar to that of the Bunsen burner. The combustion chamber, which attains an exceptionally high temperature, is provided with large iron doors at each end, for the admission of infected or other articles, and also for access for the periodical removal of fine ash from the flues.

The Beaman and Deas furnace being a good steam or power producer, a boiler to each pair of cells may be advantageously fixed in combination therewith for the supply of power for any purpose for which it may be required, such, for example, as the driving of fans, lifts, pumping, or other machinery, or for generating electricity. The boiler shown in the illustration is a water-tube boiler of the Babcock and Wilcox type, and is heated by the gases from the combustion chamber which pass, on their way to the main flue, three times between the boiler tubes. A secondary furnace is shown under the boiler for raising steam when the cells are out of use.

The original points claimed by the patentees for their invention are, briefly: a destructor furnace consisting essentially of a flat or inclined furnace grate, an inclined feeding hearth, a reverberatory arch extending over the grate and hearth, a vertical perforated fire-brick screen, a fire-bridge, and a chamber formed between the screen and the bridge.[1]

The process of burning the refuse is, briefly, as follows: — The material to be consumed is carted to the tipping platform, and, without undergoing any process of screening or selection, is discharged through the hopper, as above referred to, on to the inclined hearth. A charge is meanwhile in course of destruction on the horizontal fire-grate, and when this is consumed the furnace is clinkered, and the charge lying on the inclined hearth, which has meanwhile, to a considerable extent, been dried by the heat deflected from the fire-brick hearth and the general heat of the furnace, is in turn drawn on to the horizontal fire-grate, and another charge takes its place on the inclined hearth. The clinkering and re-charging of the furnace is done alternately, the better to preserve the heat in the combustion chamber, which is stated to be maintained at a temperature of 2000 deg. Fah. Inasmuch as all the products of combustion have to pass through this chamber it is impossible for any undecomposed vapours to escape into the main flue beyond, and one of the most important of all questions appertaining to the disposal of refuse, viz , the absolute avoidance of nuisance, is thus provided for.

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[1] Patent No. 23,712 (1893).

In relation to the efficiency of the working of the Beaman and Deas furnace, Mr. C. Estcourt, F.I.C., Analyst to the City of Manchester, has made the following observations in his report on the destructor at the Longford depôt of the Warrington Corporation :—" In the first place, I may state that in my opinion (grounded upon the observations I have made) the use of this destructor does not cause the slightest offence or nuisance; secondly, that the refuse dealt with is reduced to a very small quantity of clinker, containing no organic matter. I took particular notice of the chimney shaft, and I may say at no time did I see any charred paper or any other dust coming from it. . . . From my examination of the gases coming from the chimney shaft, I am quite sure that they are perfectly innocuous, and free from anything harmful. No organic or mephitic vapour can escape even into the flue during the process of combustion in this destructor.

" I have made analyses of the gas drawn from the chamber in the flue, under all the three main conditions of working, *i e.*, (1) immediately before clinkering; (2) during clinkering; (3) immediately after clinkering, when the new charge of refuse had been drawn into this destructor, and I can state that I did not find any harmful gas escaping from these furnaces.

" I found no trace of sulphuretted hydrogen. There is no trace of carbonic oxide, showing that practically *perfect combustion* is attained by this destructor.

" I observed, also, that during the process of burning the silicious particles, &c., appear to be carried in a fused condition up to the arch of the furnace, and attach themselves to the brickwork, thus *forming a complete protection to the furnace,* and obviating the danger to which many destructors are subject, of being burnt out. I was shown a brick from the arch, which had been in fourteen months, and which gave no sign of wear."

In regard to the formation of these stalactites upon the roof of the furnace, Mr. J. Carter Bell, F.I.C., of Manchester, observes, in a report on the Warrington Destructor,[1] that objections may be taken to the great heat generated on the grounds of its being likely to destroy the lining of the furnace; but, as a matter of fact, "this great heat is an immense advantage, for through the blast which is blown in a fine spray or shower of clinkers is formed, which fixes itself upon the roof and exposed portions of the furnace in a stalactitic form, thus protecting the brick lining from the intense heat. Some of these stalactites were knocked off in my presence, which I have analysed, and the following is the analysis :—

Silica	55·364
Oxides of iron...	15·711
Alumina	17·362
Lime	5 390
Magnesia, potash, soda, sulphuric acid	6·173
	100·000

"This furnace has been at work since August, 1893, and is as good now as the day it was erected. I consider the furnace to be a perfect destructor, and very much superior to any others I have seen."

Another very important point has been pointed out by Mr. C. Estcourt, viz., that pieces of paper and other light material lying in any part of the furnace, even directly over the blast, retain their position until consumed. One serious source of nuisance common to other forms of destructor is thus avoided, namely, the emanation from the chimney shaft of pieces of charred paper, &c.; also the fumes from the fresh charge, lying upon the hearth, pass through the fire directly over the fire-bars.

In March, 1896, a series of tests on the Beaman and Deas furnace at Warrington were made by Mr. F. F. Bennett, M.I.E.E., of Preston, for the purposes of his report to the Electric Lighting Committee of the Radcliffe Urban District Council, who have had the question of a joint destructor and electric lighting scheme under their consideration. During a *six-hour* test it appears that 9 tons 13 cwt. 3 qr. of Radcliffe town refuse were consumed. The average of thirteen readings during the test gives the following results :—

Steam pressure	45 lb. per square inch.
Temperature of feed-water	141·5 deg. Fah.
Temperature of *flue* gases	519 deg. Fah.
Draught in *flue*	¼in. (water gauge).
Draught in *ashpit*	2·5in. (water gauge).

Each furnace was charged once every half-hour—a charge consisting of 16 cwt. 16 lb. of refuse. The weight of water evaporated was 22,000 lb., and therefore, for every 1 lb. of refuse destroyed, 1·11 lb.

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[1] Report, June, 1894.

of water was evaporated. The material contained a considerable quantity of moisture, being 48·44 per cent. of the whole. Had the refuse contained no moisture, the amount of water evaporated would have been 1·98 lb. for every pound of dry refuse destroyed, so that the drier the refuse the better the result.

With a good compound condensing engine, requiring the evaporation of 20 lb. of water per indicated horse-power, the result of the test would have been a development of 1100 indicated horse-power, or 183 indicated horse-power per hour. Working on the basis of a former report, Mr. Bennett calculates that "this would supply sufficient energy for 3660 30-watt lamps per hour. In other words, with 10 tons of refuse, a pair of Beaman and Deas destructors, and one Babcock and Wilcox 200-horse power boiler, you would be able to run 3660 30-watt lamps for a period of six hours, and if the refuse is in a drier condition, a still better result would be obtained. With two pairs of destructors and two such boilers, with fan and pump, including delivery and erection, and costing about £3660, double this quantity of lamps could be supplied per day, requiring about 120 tons of refuse per week."

One pound of ordinary slack coal will evaporate from 4 lb. to 6 lb. of water; and 1 lb. of good coal from 8 lb. to 10 lb. of water. It may therefore be safely assumed that house refuse, for heating and evaporative purposes, is equal to 25 per cent. of the value of slack.

Huddersfield Corporation Test at Warrington.—As this Authority wished to ascertain what the Beaman and Deas furnace could accomplish with their refuse and sludge they sent to the Warrington destructor 4 tons 12 cwt. of *sludge*, which was mixed with 6 tons 12 cwt. of *refuse*—a proportion of not quite 1½ to 1—making a total of 11 tons 4 cwt. This was burnt in 5¾ hours, being at the rate of 24 tons 9 cwt. per cell per day of 24 hours. The residue of the whole amounted to 2 tons, or 17·85 per cent.

The amount of water evaporated on the occasion of this test was 32,000 lb., which equals 1·27 lb. of water per pound of refuse and sludge consumed, with the feed-water from and at 65 deg. Fah.

The sludge at Huddersfield is of a moist description, and the sample sent was thoroughly saturated by being exposed to heavy rain.

The test was carried out in the presence of two of the Huddersfield Corporation officials, namely, the Assistant Surveyor and the mechanical engineer.

The following are some of the chief results obtained at the Warrington installation in a twenty-four hour test made in November, 1893, by Mr. G. Darley, Superintendent Ashpit Cleansing Department, Leeds, and Mr. G. T. Carter, of the City Engineer's Office, Leeds :—

Nature of fuel	Unscreened refuse.
Quantity of fuel per hour	2231 lb.
Quantity of water per hour (evaporated) ...	2556 lb.

$$=\frac{2556}{20}=127\text{ I.H.P.}$$

Percentage of clinker	27·9
Pressure of steam maintained	68 lb.
Temperature of air in boiler-house	45 deg. Fah.
Temperature of feed-water	104 deg. Fah.
Temperature of gases leaving damper ...	650 deg. Fah.
Quantity of water evaporated per pound of refuse	1·14 lb.
Average temperature by copper wire test...	2000 deg. Fah.
Average air pressure (water gauge) maintained...	2½in.
Draught velocity in feet per minute	820.

Another test, of 5⅝ hours' duration, made on behalf of the Warrington Corporation in March, 1896, with a fair sample of Warrington refuse, gave the following results :—

Weight of refuse discharged on furnaces per hour	3173 lb.
Amount of moisture in refuse	30 per cent.
Percentage of clinker	15·4
Average steam pressure carried in boiler ...	53 lb.
Average temperature of feed-water	135 deg. Fah.
Weight of water evaporated per hour ...	4·766 lb.
Weight of water evaporated per pound of unscreened refuse	1·5 lb.
Weight of water evaporated per pound of unscreened refuse, assuming feed 212 deg.	1·66 lb.
Water evaporated per pound of refuse, assuming it in dry state...	2·1 lb.
Water evaporated per pound of refuse, assuming it in dry state and feed-water at 212 deg.	2·32 lb.
Temperature of flue gases	576 deg. Fah.
Draught in flue in inches of water	$\frac{9}{16}$in.
Draught in ashpit	2in.

As regards the capacity of this type of destructor it has been found capable of dealing with 24 tons of house refuse per cell per 24 hours, whilst the *average* consumption of the furnaces named in the accompanying table (compiled in 1892 by Mr. G. Watson) will be seen to be 6·3 tons per cell per 24 hours. The table is as follows:—

Name of town.	Number of cells.	Make of cells.	Average tons burnt per day of 24 hours.	Equal to tons per cell per 24 hours.	Cost of burning per ton. Returns deducted in each case.
					s. d
Battersea	12	Fryer's	81¾	6·81	2 2½
Bradford	24	Fryer's, fitted with Horsfall's steam jet	170	7·09	1 5
Ealing...	4	Fryer's	20	5·00	0 4½
Hornsey	6	Warner's	35	5·83	0 10¼
Leeds	Burmantofts, 14	Fryer's, fitted with Horsfall's steam jet	216	6·00	1 7¼
	Armley-road, 12	Do. do. do. do.		6·00	
	Kidacre-street, 10	Combination of Fryer's and Horsfall's		6·00	
Leicester	6	Fryer's, with Biddle's patent grate bars	33	5·50	1 3
Newcastle-on-Tyne ...	6	Warner's	48	8·00	1 0¼
Southampton	6	Fryer's	50	8·33	Profit 2¾
Bolton	8	,,	50	6·25	0 2½
Bury	4	,,	20	5·00	1 10½
Liverpool	12	,,	96	8·00	1 3
Salford	6	,,	28	4·66	1 6
Whitechapel	8	,,	60	7·50	2 8
Oldham	6	Horsfall's	37½	6·25	1 1

Assuming the consumption of a Beaman and Deas cell at the rate of 24 tons of unscreened refuse per 24 hours, and an average water evaporation of 1 lb. per pound of refuse,[1] the theoretical value of a cell in indicated horse-power, supposing an engine to consume 20 lb. of steam per indicated horse-power per hour, would be $\frac{2240}{20}$ (pounds of water evaporated per hour) = 112 indicated horse-power continuously all the time of working.

At the Leyton installation of the Beaman and Deas destructor (which has been built not only for the cremation of house refuse, but also for the disposal of pressed sewage sludge cake from the Leyton Sewage Works), many tests have been made by various Public Authorities in the burning of house refuse, slaughter-house offal, market vegetable refuse, &c., of which the following are some of the particulars:—

St. Pancras Vestry Test at Leyton.—On the morning of May 11th, 1897, a consignment of refuse amounting to 18 tons 13 cwt. 3 qr. was taken down to Leyton by the Vestry's contractor for the collection of house refuse. The charging of the first cell commenced at 7.30 a.m., and that cell continued at work until 7.20 p.m., having destroyed in that time eight charges. The work on the other cell was commenced at 7.55 a.m., and continued to 9.15 p.m. This cell also destroyed eight charges.

The average time the fires were at work was therefore 12 hours and 40 minutes, during which time 16 tons 13 cwt. 3 qr. were consumed, being at the rate of 15·8 tons per cell per day of 24 hours. It should, however, be stated that owing to a mistake in placing too heavy a final charge in the second cell, a considerable delay occurred, otherwise the quantity burned per cell would have been higher.

Two men only were needed for the work, and charging their rate of pay at the same as is paid by the Vestry, viz., 6½d. per hour, the cost of burning the refuse was 9¾d. per ton.

The rate of temperature throughout the test was very high indeed, beyond the range of the ordinary test, probably between 2000 and 2500 deg. Fah., and with such a temperature there was, of course, no difficulty in keeping up the steam pressure in the boiler. In fact, the hot air had to be passed through the bye-pass flue, as the boiler commenced blowing off steam one hour after the commencement of the test.

The test was carried out in the presence of the Vestry's engineer, Mr. W. Nisbet Blair, and the Superintendent of the St. Pancras Destructor Works.

Deptford Cattle Market Refuse Test.—In this test 6 cwt. 2 qr. of slaughter-house offal were mixed with 12 cwt. of gasworks breeze, making a total of 18 cwt. 2 qr. The whole quantity was completely consumed in fifty minutes.

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[1] *Vide* paper on "The Disposal of Town and other Refuse by Burning," by James Deas (*Journal of Sanitary Institute*, vol. xvi., page 17).

The residuals amounted to 2 cwt. 3 qr., or 14·86 per cent. The temperature in the combustion chamber is stated as having been over 2000 deg. Fah. This test tends to prove that this class of refuse can be successfully dealt with in a Beaman and Deas furnace in a proportion of 1 of refuse to about 1¼ of coke breeze.

Whitechapel District Board of Works Test.—This test was made by the Whitechapel Authorities in March, 1897, as some difficulty is experienced in the cremation of vegetable garbage by the destructors (Fryer's) at present in use in that district.

As a result of the test, Mr. J. Paget Waddington, the engineer and surveyor to the Whitechapel Board of Works, reported to the effect that the refuse, which consisted of about equal proportions of green vegetables and wet straw collected from the Spitalfields Market, together with rough house refuse from the Whitechapel district, was conveyed to Leyton and consumed in the Beaman and Deas furnaces at an average rate of 24 tons per cell per 24 hours. The quantity of clinker produced was 20 per cent. of the whole, and resulted mainly from the house refuse in the mixture. The clinker was of excellent quality, being hard and clean, and no unconsumed refuse was drawn from the furnaces while clinkering operations were performed. The temperature of the combustion chamber was maintained at a high degree during the time the refuse was being burned, and apparently at no period of the trial were unconsumed fumes given off from the furnaces.

Report and Tests by Sir Douglas Fox, M.I.C.E., on the Leyton Refuse and Sludge Destructor, erected under the Beaman and Deas' patents:—As the installation at Leyton is, so far as I am aware, the first destructor which satisfactorily deals with the disposal of pressed sewage sludge, and as the works have excited considerable interest amongst Public Authorities, the details of a test and examination conducted in April, 1897, by Sir Douglas Fox, cannot fail to be of interest to municipal engineers and surveyors. The particulars are as follows:—

"*Construction of Plant.*—The plant consists of eight destructor cells, built in pairs back to back. Each pair of cells has a common combustion chamber, from which the products of combustion pass into the main flues leading to two 96-horse power Babcock and Wilcox water-tube boilers, and thence by underground flues to a chimney 150ft. in height.

"The refuse to be consumed is charged through hoppers (which have no doors, but are usually covered with the refuse) on to an inclined hearth leading to a horizontal grate, the bars of which are set very close together. The ashpit is closed and a forced draught, at a pressure of about 2in., is supplied by a fan. On the side of the grate opposite that from which the refuse is fed in is a fire-brick chamber wall, and beyond this is a narrow vertical fire-brick chamber (called the combustion chamber), where the burning gases meet a secondary air supply, designed to aid the consumption of any unoxidised products which they may contain.

"The refuse about to be burned, lying on an inclined hearth, is partially dried by the radiant heat from the refuse which is already burning on the grate; and when it is drawn down on to the grate does not smother the fire, but begins to burn readily.

"*Outline of method of Trial adopted.*—A twelve hours' trial was carried out on Tuesday, March 30th (1897). Two pairs of cells were used, the remaining two pairs being left cold throughout the run. In the course of the trial the character of the refuse burned, and the quantity of refuse consumed, the amount of water evaporated in the boilers, and the weight of clinkers produced, were observed and determined. A special examination was also made of the nature of the escaping gases, and numerous samples for analysis were taken. The temperatures of the combustion chamber and of the flue gases were also ascertained, and the results in detail are set forth below.

"*Character of the Refuse Consumed.*—The refuse consumed consisted of a mixture of ordinary *house refuse and filter press cakes of sewage sludge* from the Leyton Sewage Works. These were used as nearly as possible in the proportion of two parts of house refuse to one part of sewage sludge by weight.

"Observation of the character of the house refuse during the day showed that it was fairly dry (the weather being fine), but of rather poor quality from a heat-producing point of view; that is to say, the quantity of cinders was small, such refuse of household fuel as was present being to a great extent merely fine ash, containing but little combustible material. A considerable part of the refuse consisted of old tins and crockery, and there was also a good deal of green vegetable refuse, probably more than the usual average.

"The other material consumed—the sewage sludge—arrived from the filter presses in a wet, pasty condition. It was analysed both for moisture and the percentage of combustible material (carbonaceous matter) which it contained. The proportion of water exhibited some fluctuation, as is apparent from the following analyses:—

	Water per cent.
Sample A	61·23
Sample B	68·50
Average	64·86

"The average amount of combustible carbon was also determined.

Carbon calculated on the dried sewage cake, 18·49 per cent. This quantity corresponds with 6·50 per cent. of combustible carbon on the wet sewage cake containing 64·86 per cent. water.

"It will have been seen from these figures that not only is the sewage cake very wet, but that it contains only a small percentage of combustible matter. A mixture of one part by weight of this material and two parts of house refuse of low quality is therefore a very poor fuel.

"*Steam-raising Value of the Refuse and Sewage Cake.*—Duration of trial, 10 a.m. to 10 p.m., March 30th, 1897 = 12 hours. Number of cells of destructor in use, 4.

Detailed Results of Trial.

	Tons.	cwt.	qr.	lbs.
Weight of house refuse consumed ...	22	5	0	= 49,840
Weight of sewage cake consumed ...	11	4	1	= 25,116
Total weight of material burnt	33	9	1	= 74,956
Proportion of house refuse to sewage cake	100 : 50·4 = 2 : 1 (nearly)			
Average weight of material burnt per cell per hour				1,561
Total weight of clinker produced ...	9	16	2	= 22,008
Proportion of clinker produced to material burnt				29·4 per cent.
Average steam pressure in boilers				105
Average temperature of feed-water				65 deg. Fah.
Weight of water evaporated	3192 gals.			= 31,920
Weight of water evaporated per hour				2,660
Weight of water evaporated per lb. of material burnt...				0·426

Corresponding with :—

Weight of water evaporated per lb. of material burnt from and at 212 deg. Fah.	0·507
Average pressure of air in ashpit	2 in. of water.

"The extremely low quality of the material consumed (poor house refuse and wet sewage cake) is indicated by the small quantity of water evaporated per pound of fuel (0·426 lb.). In spite of this, the total power produced was considerable; taking the total weight of water evaporated as 31,920 lb., and assuming an average consumption of 20 lb. of water per indicated horse-power, the horse-power available would be 133 indicated horse-power; the equivalent amount of steam coal which would be required to obtain this result is 1¾ tons, representing a cost of £1 11s. 6d., assuming the price of coal to be 18s. per ton delivered at the works.

"The total heat available was more than sufficient to heat the boilers, and these in their turn supplied more steam than was re-

required for the needs of the works, which was served by a 45-horse power engine in the sewage works, and by a 12-horse power engine in the portion occupied by the destructors. A smaller engine drove two fans delivering air to the ashpits of the cells, a dynamo lighting the works and a steam hoist for raising the sewage to the charging floor, and a feed-water pumping engine was also provided with steam from the boilers. The larger engine drove a pump lifting sewage from low to high level, an air compressor for the filter press, and all minor plant in the sewage works.

"*Completeness of Destruction of Refuse.*—During the trial attention was specially directed to the question as to how far the destructor accomplished its work in consuming the wet and objectionable refuse supplied to it in such a manner as to leave nothing but innocuous products. This portion of the inquiry appears to us to be of fundamental importance, in that complete combustion of noxious and putrescent refuse is of greater moment than is the production of power as an incident in its consumption.

"The ultimate materials constituting the output of the destructor are clinker and gaseous products of combustion; both should be as fully oxidised as possible. Accordingly, analyses of the clinker and gases were made with the following results:—

"(I.) *Clinker.*—The quantity of unburnt carbonaceous matter was determined, carbon 2·10 per cent. The amount of combustible material left in the clinker is therefore extremely small; moreover, it is present as well-charred particles, and is no more objectionable than that commonly present in furnace ashes.

"(II.) *Gaseous Products of Combustion.*—Samples were taken both from the combustion chamber of one of the destructor cells and from the boiler flues at the point where they were connected with the underground flue leading to the chimney.

A.—*Gases from Combustion Chamber.*

	Percentage by volume.	
	1.	2.
Carbonic anhydride (CO^2)	6·9	6·7
Carbon monoxide (CO)	Nil	Nil
Oxygen (O)	12·9	12·8
Nitrogen (N)	80·2	80·5
	100·0	100·0
Corresponding with free air	61·4	61·0

B.—*Gases from Boiler Flue.*

	Percentage by volume.				
	1.	2.	3.	4.	5.
Carbonic anhydride (CO^2)	2·7	4·2	5·0	3·6	4·9
Carbon monoxide (CO)	Nil	Nil	0·4	Nil	0·2
Oxygen (O)	17·2	14·8	14·5	15·9	14·4
Nitrogen (N)	80·1	81·0	80·1	80·5	80·5
	100·0	100·0	100·0	100·0	100·0
Corresponding with free air	81·9	70·5	69·0	75·7	68·6

"From these figures it is evident that substantially complete combustion is effected, carbon monoxide (a product of incomplete combustion) being usually absent; and, when present, existing only in negligible quantity in the flue gases. That the combustion was thorough was further proved by frequent observation of the smell of the flue gases; they were found to be free from offensive odour, and to contain no evil-smelling product of destructive distillation or imperfect oxidation. This is of importance, because the consumption of wet refuse is likely to give rise to objectionable gaseous products, unless steps are taken (as in this case) to oxidise the products thoroughly before they pass into the chimney flue.

"On account of this fact it is desirable that there should be an ample supply of air, over and above the calculated quantity necessary for the complete oxidation of the carbonaceous matter. In the case of the samples examined this condition is fulfilled, inasmuch as they contain from 61 per cent. to 81·9 per cent. of free air. It is possible that it may be found practicable somewhat to diminish this large excess of air, without impairing the completeness of combustion, and with a gain in efficiency in heating the boilers. At present, however, the total heat available is so much greater than that which can be usefully employed, that this increase of efficiency is of no immediate importance.

"*Retention of Dust by Destructor.*—Not only is it necessary that the products of combustion from an efficient destructor should be fully oxidised, but it is also highly desirable that they should be as free as possible from dust and smoke.

"The behaviour of the destructor in this respect was ascertained by filtering a known volume of gas drawn from the combustion chamber, and determining the weight of dust thus separated. The quantity found was:—Dust per cubic foot of gas from combustion chamber, 0·18 grain.

"The amount is, therefore, inconsiderable, even at a point so close to the grate as to allow but little time for the deposition of any suspended matter which might be scattered by the blast of air supplied to the ashpit. Many larger particles of slag (as distinct from fine dust) passed over into the combustion chamber in a state of incandescence. These being in a semi-fused state, adhered to the walls of the chamber, and formed a protective coating on the brickwork against injury either by heat or attrition.

"A trial was also made of the gases passing from the boiler flue to the chimney. In this case the quantity of dust was found too small to estimate.

"Observation of the smoke from the chimney, made at frequent intervals during the trial, showed that the amount emitted was unusually small. It was light brown in colour, and was readily dissipated within a short distance of the mouth of the chimney.

"Considering these facts conjointly, it is evident that during the trial almost complete retention of dust was effected.

"*Temperature of Combustion Chamber.*—The temperature of the combustion chamber when the charge was burning freely was determined and found to be:—

850 deg. Cent. = 1562 deg. Fah.

"This corresponds with a moderate red heat, and is sufficient to complete the combustion of any unburnt products escaping from the grate.

"Naturally, if refuse only of fair average quality was consumed, the heat would be much greater—probably more than 2000 deg. Fah.

"*Temperature of the Flue Gases.*—Observation of the temperature of the gases in the underground flue leading to the chimney was made at intervals during the trial. It was found to fluctuate somewhat according to the stage of firing the cells; the temperatures taken are as follows:—

No. of Observation.	Temperature of the Flue Gases.		
1	230 deg. Cent.	=	446 deg. Fah.
2	320 ,,	=	608 ,,
3	250 ,,	=	482 ,,
4	270 ,,	=	518 ,,
5	238 ,,	=	460 ,,
6	227 ,,	=	440 ,,

"The comparatively high temperature of the flue gases is due to the fact that during the trial more heat was being produced by the destructor than could be absorbed by the boilers, the furnaces being indeed capable of generating a good deal more power had a third boiler been available. The two boilers in use were blowing off at 110 lb. pressure throughout the test.

"*Examination when Cold.*—We examined one of the cells in its cold condition, and were unable to discover any signs of wear or abrasion.

"*Conclusions.*—From a consideration of the results of this trial we have arrived at the following conclusions:—

"(1) The destructor is capable of consuming wet sewage-cake, and house refuse of poor character in a complete and satisfactory manner.

"(2) The oxidation of the combustible matter in the material fed into the destructor is complete, and the gaseous products of combustion are inoffensive.

"(8) The gaseous products of combustion are sensibly free from any suspended matter by the time they pass into the flue to the chimney.

"(4) The clinker is well burnt and free from offensive half-charred carbonaceous matter.

"(5) Even when working with a wet sewage-cake, and poor house refuse, the destructor generates more heat than can be used with the present plant at Leyton.

"We therefore consider that this destructor provides an efficient and economical method of destroying the refuse of towns without injury to the neighbourhood. So far as we are aware, it is the only form of furnace yet adopted capable of burning a considerable proportion of sewage sludge—even when containing, as in this case, a high percentage of moisture."

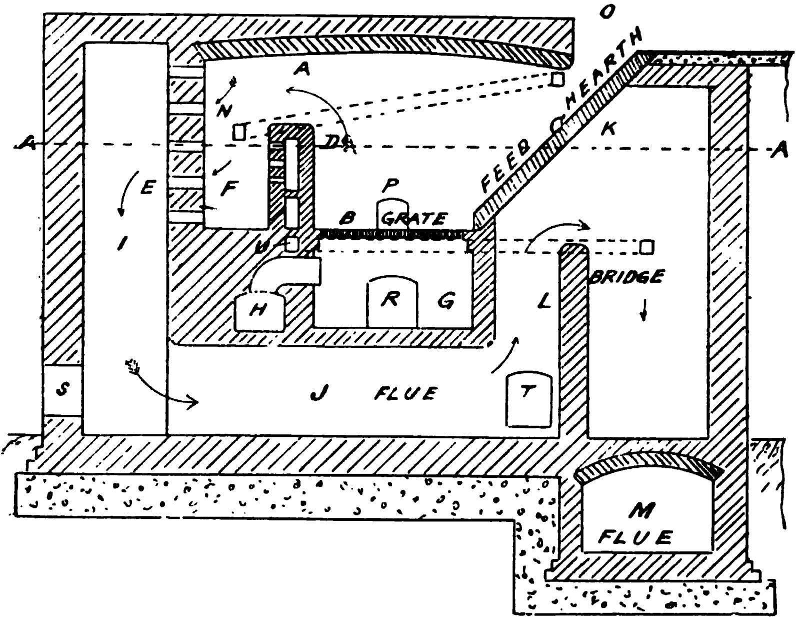

Fig. 22.—Section of Beaman and Deas's Sludge Furnace.

The Beaman and Deas Sludge Furnace.[1]

Messrs. Beaman and Deas have also a further patent furnace for burning sludge from sewage works, from manufacturers' settling tanks, and the slurry or slip produced in the manufacture of Portland cement and other similar materials. The construction of the furnace is illustrated in the accompanying figures (22 and 23), in which

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[1] Patent No. 18,029 (1894).

A = a reverberatory arch,
B = the fire-grate,
C = the inclined feeding hearth,
D = a hollow fire-bridge,
E = a perforated screen,
F = a secondary combustion chamber,
G = the ashpit, which is closed and provided with a forced draught through the air conduit H.

At the back of the secondary combustion chamber is an auxiliary chamber flue or passage I, communicating through flue J with the space K under the inclined feeding hearth. In this space (K) a bridge L is erected for the purpose of deflecting the hot gases upon the under side of the feeding hearth, from whence they make an exit through a flue M to the chimney shaft.

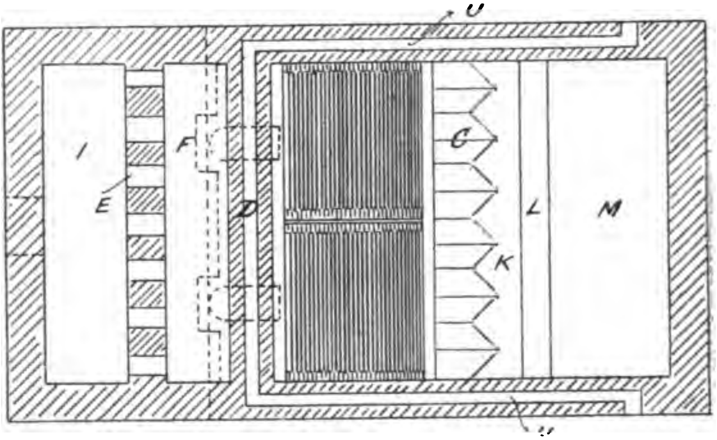

Fig. 3.—Plan of Beaman and Deas's Sludge Furnace.

The feeding-hearth consists of flanged angle bars arranged closely together and connected by bolts or rivets passing through the flanges.

Instead of allowing all the furnace gases to pass directly over the bridge D, some of them may be taken from a point over the inclined feeding hearth into a scondary combustion chamber through the hollow bridge, where they mingle with the incoming air, or the gases may be conveyed from the upper part of the inclined hearth direct to the secondary side of the furnace.

These furnaces may be built singly or in groups similar to ordinary destructor cells. The sludge or refuse material to be burnt is supplied to the upper part of the feeding hearth through a small opening (O) about 18in. square, which aperture is kept closed by the supply of refuse whilst the furnace is in use. The material thus supplied to the hearth is dried in the course of its downward passage to the grate, thus assisting its more rapid combustion. At P is a door through which the grate may be cleared and the clinkers removed. Dust is removed from the ashpit through door R, and from the flues and chambers below the furnace and hearth through S and T. Fresh air is supplied to the hollow bridge through the passages U. The products of combustion from the furnace, after passing the perforated screen, are caused to return through suitable flues to below the inclined feeding hearth, which becomes highly heated thereby.

Should there be no combustible matter in the sludge, &c., to be burnt, a sufficient quantity of breeze or other suitable combustible material is mixed with it.

The novel points claimed by the patentees for this type of furnace, in brief, are as follows :—

(1) The provision of a chamber or space below an inclined feeding hearth, into which chamber the hot gases from the furnace are led in such a manner as to impart their heat to the hearth.

(2) An inclined feeding hearth having a sinuous or zigzag cross section, and having also a space below it into which the products of combustion are led.

(3) Passages or flues connecting the interior of the furnace near the upper part of the hearth with a hollow fire-bridge or a secondary combustion chamber.

HANSON'S DESTRUCTOR AND UTILISER.

This is a recent invention of Mr. John Hanson, of Wakefield. The main points claimed for the apparatus are as follows :—

(1) A total absence of all fumes.
(2) Cheap first cost.
(3) A large capacity for given cost.
(4) It occupies small ground space for given capacity.
(5) It leaves a residue easily disposed of, and in certain cases saleable.
(6) The cost of treatment by it compares favourably with that of any other system.

The absence of fumes, it is stated, is attained by drawing, from the retorts, the fumes and steam given off by the stuff in drying and forcing them *under* the furnace bars with the forced draught.

A complete set of three Hanson retorts, with boiler in one setting, over three furnaces, with the necessary engine, shafting, screws for conveying material through retorts, riddles, elevators, chimney, &c., cost £1000 erected and ready for work in any part of England. The capacity of this set, as measured over twenty weeks' working at

Wakefield, is two tons per working hour, or a capacity of 48 tons per twenty-four hours; and deals with ashbin refuse, midden stuff, offal, and garbage.

The ground space occupied is comparatively small. A set of three Hanson retorts (as at Wakefield) measures 17ft. long and 12ft. deep, *i.e.*, it occupies a space of 204 square feet for a capacity of 48 tons per twenty-four hours.

The amount of clinker produced is said to be about six tons per 100 tons of refuse dealt with.

At Wakefield the cost of disposal is given at 1s. 3d. per ton.

Further, as bearing upon the question of economy, it is claimed that the Hanson destructor—requiring no expensive chimney or foundations, occupying little space, having large capacity, and working without smell or nuisance—lends itself to a system of small isolated destructors, each dealing with the refuse of the adjacent district, and so minimising cost of cartage of the refuse. It would appear, however, under such a system, that the cost of management and working must necessarily be increased in proportion to the number of such stations.

The above apparatus was also erected for the Corporation of West Ham.

From a report[1] of a deputation of the Board of Works for the Wandsworth District appointed to visit places in which dust destructors are in use, it appears that Hanson's apparatus was considered by the deputation, and that Mr. Hanson made the two following offers:—

(*a*) To treat the town refuse, not less than 140 tons per week, at a rate of 1s. 3d. per ton; the Board to pay 1s. 3d. per ton for the clinker that they require; the Board to provide land, weighbridge, and buildings of a temporary nature, and to collect the dust and deposit it day by day near the utiliser. The account to be paid monthly. He guaranteed to clear away all the surplus at his own cost, and that there should be no nuisance from the process.

(*b*) To erect for £1000 *one machine* called a "*utiliser*" to dry the cinders for fuel and the ashes for bricks and mortar; *two destructors*, side by side, to burn paper, rags, bones, dead animals, door-mats and bedding, also to melt the tin of meat cans, &c.; *one machine* to crush the tins for hard core or old iron.

He stated that the power from the machine and destructors would be 40 indicated horse-power, which would be available for mortar grinding, &c.; and that the above plant would deal with 80 tons per day.

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[1] Dated May, 1897.

Mr. Hanson was questioned on various matters connected with his method, and he stated that he only required a chimney some 25ft.

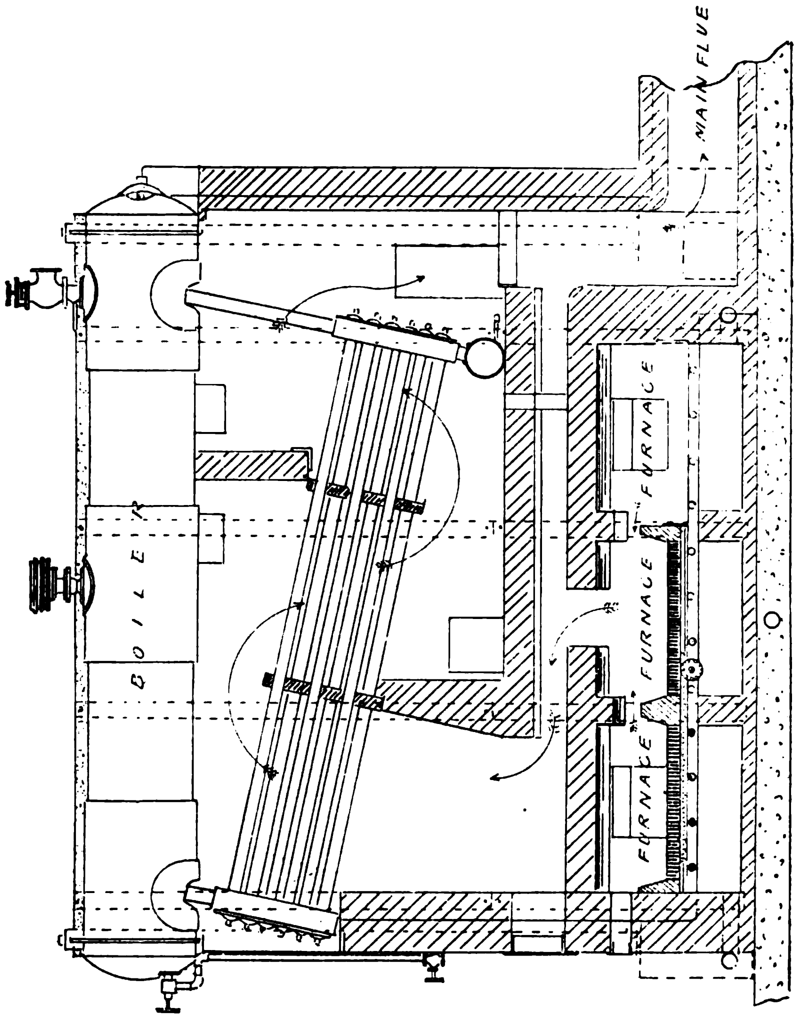

Fig. 24.—Section of the "Bennett-Phythian" Destructor.

high, from the top of which neither smell, smoke, nor smuts would issue, as all the offensive vapours pass through a second fire. The rubbish generally would be sifted by machinery, and the feeding of the utiliser would be done by mechanical elevators. The destructors, however, which would consume the larger material, would have to be fed by hand.

At West Ham six men were employed to deal with refuse at the rate of 60 tons per twenty-four hours; that is to say, if three shifts of men were employed it would mean eighteen men to deal with 60 tons in twenty-four hours. Mr. Hanson stated that with improved plant labour could be considerably reduced.

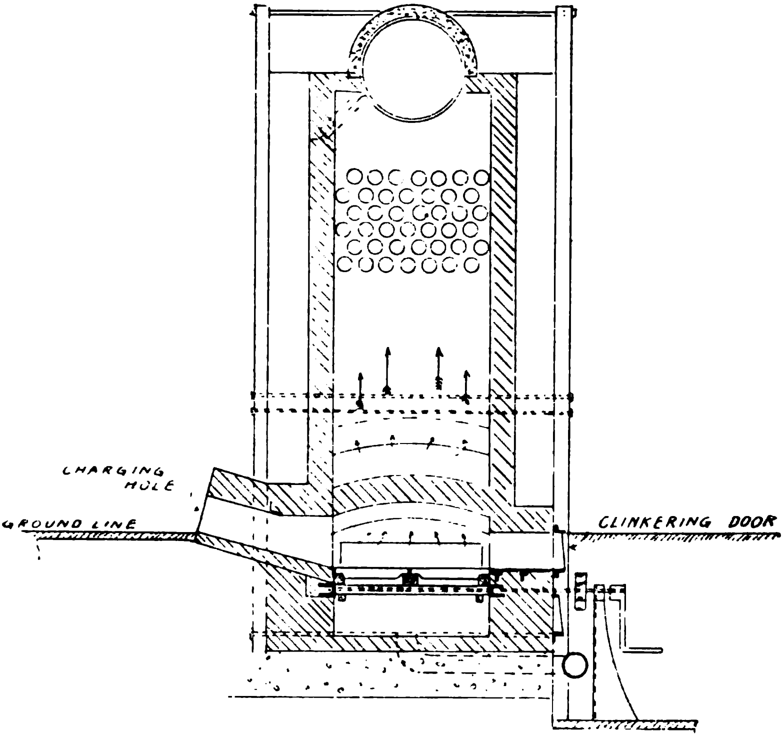

Fig. 25.—The "Bennett-Phythian" Destructor: Transverse Section.

THE "BENNETT-PHYTHIAN" DESTRUCTOR.

The "*Bennett-Phythian*" constant high-temperature destructor is an apparatus which has very recently made its appearance, and a furnace of this type has been erected by the Farnworth Urban District Council. The special features of the furnace will be apparent from an inspection of Figs. 24 and 25, and from the following description :—When at work the fires are burning upon the grate in two of the cells, the other being empty. The central cell obtains a maximum heat, and when it requires re-charging the grate is moved to bring that part which was in the central cell into the empty side cell, and that which was in the outer cell into the centre, and thus, without cooling the central cell or furnace, a fresh charge is brought into it which had been gradually increasing in heat. The grate that has been moved into the empty cell is then clinkered and re-charged, and the blast turned on to it, when it gradually increases in temperature, the products of combustion from it passing over the hotter fire in the centre, until that in its turn requires re-charging ; and thus the side cells are alternately re-charged and the grate moved to carry the charge into the central cell. The grate on which the refuse is placed may be moved by the rack-and-pinion arrangement illustrated, but an electric motor may be utilised for this purpose.

Some of the points claimed for it are :—

(1) That it is capable of destroying 24 tons of house refuse in twenty-four hours, and at the same time of raising steam for electric light or other purposes.

(2) That all gases pass over the central cell, where constant temperature is maintained at 2000 deg. Fah.

(3) No elevated roadway is required, and the charging and clinkering are done on the ground level.

THE WILLOUGHBY PATENT REFUSE DESTRUCTOR.

The Willoughby refuse destructor, as now in use at Lewisham, is the most recent type of furnace that has been adopted, and, as will be seen from the accompanying illustrations (Figs. 26 and 27) possesses several entirely new features. It consists mainly of a furnace and a revolving cell.

The *furnace* is placed at one end and fed, not with town's refuse, but with gas coke, coal. or breeze, assisted with a draught forced by Meldrum blowers, so as to give a fire of high temperature. The products of this furnace escape into a revolving cell.

This *revolving cell* consists of a long tube of iron or steel plate, lined throughout with fire-brick, and fixed at a small angle from the horizontal. The first portion of this cell or tube (Fig. 26) has a diameter of about 8ft., and the lower portion one of about 5ft. Each section is about 28ft. in length. In the inside are projecting fire-brick ledges arranged so as to give a series of longitudinal ribs which serve to catch and carry up the contents of the tube, and drop the same time after time as it passes along the length of the cell.

The tube is carried within a series of stout rings which run on bearing rollers. One ring is geared to an engine, which gives the rotary motion to the cell and actuates the residue elevator, the feed ram, and the ash screen, &c. The cell revolves slowly, and the speed

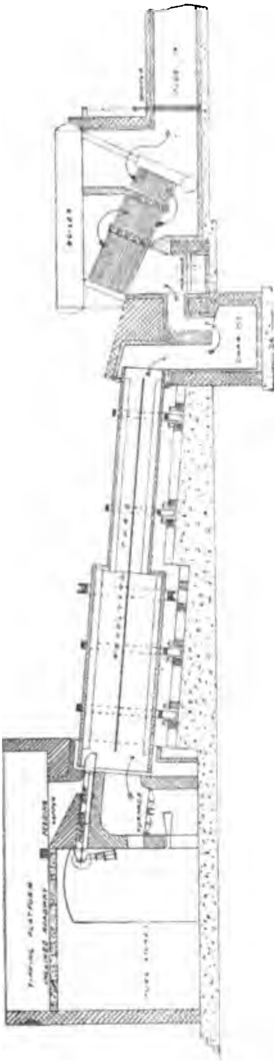

Fig. 26. Section of the Willoughby Patent Refuse Destructor.

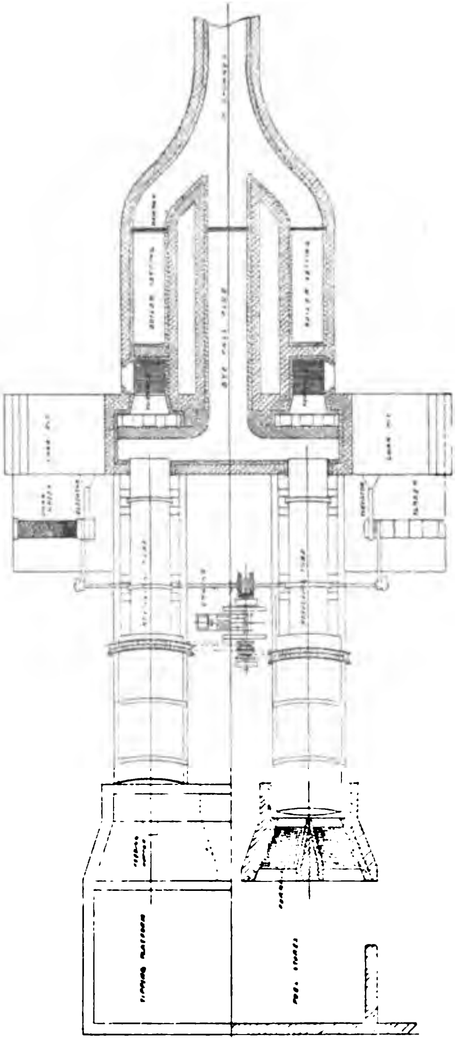

Fig. 27.—Plan of the Willoughby Patent Refuse Destructor.

is regulated according to the nature and condition of the refuse to be destroyed. Sight doors are provided through which the interior of the cell is fully visible.

The refuse is brought, as usual, up an inclined roadway, and delivered on to a tipping platform near the feeding hopper, which is placed over the coke furnace. A large slowly-reciprocating ram enters the base of the hopper and pushes the refuse along a short tube, which terminates at the upper end of the revolving cell. The lower end of the cell opens into a charpit, which serves as a receptacle for the unburnt residue from the cell. Beyond this pit is a multitubular steam boiler and secondary furnace—for use only when the destructor is idle—and flues leading to the chimney.

When the destructor is first put into action, the furnace at the front end is lighted, and a few hours are required to get the cell and walls of the chamber to a glowing heat. Then the ram is started, and about six times per minute a small portion of refuse is passed into the hot cell. Falling as this does immediately in front of the furnace on the red-hot walls of the cell, all light burnable stuff is immediately consumed, and no screens are necessary to keep paper from getting out of the chimney top as in some destructors. The fumes or gases arising from the burning of semi-putrescent matter which constitutes a considerable part of a town's refuse, become thoroughly burnt, having to pass along the whole length of the glowing walls of the revolving cell before finding their way into the flue. No two lots of refuse delivered by the ram fall upon the same spot of the cell at one time, and therefore no heaping up and stewing of green refuse is likely to take place. By the revolving action of the cell, and its inclination towards the charpit, the refuse is gradually carried away from the front until what is left unconsumed is delivered into this chamber.

This unburnt residue consists of chards, tins, glass, and cinders, but *no clinkers*. The longer the refuse takes in passing through the cell the less cinders are delivered. These at Lewisham find a ready sale, and the only residue for which there is no market consists of tins, glass, chards, and similar unburnable material. The whole of the residue is delivered in a state of bright incandescence, and is entirely free from any organic matter.

As the residue escapes it is quenched with water, and passed up an elevator to a graduated revolving inclined wire screen, which sorts to size and rejects the tins, sheet iron, &c.; the sand is separated out for the use of builders and others, and the breeze or cinders for fuel.

In the long flue leading to the chimney shaft is a water screen about 4ft. from back to front. This screen separates out the dust from the flue gases, and discharges it with the water into a pit, from which the dust is removed as required.

There is *no clinker* to deal with from the refuse passed through the Willoughby destructor, and at Lewisham, where the first installation of this furnace and plant has been laid down, the only portion of the unburnt refuse which has to be carted away is the chard, &c., amounting to about 4½ per cent. of the refuse treated.

Four men with one such cell as shown in Fig. 26 would, it is estimated from the Lewisham experience, pass through four tons of refuse per hour. One man attends to the ram feeder, one to the coke fire and the engine, and two on the unburnt residue. The wages for four men for this work would, of course, vary with the locality; but, taking a rate of pay of 6d. per hour, the *cost of labour per ton* of refuse passed through the destructor is put down at 8d., and the *cost of fuel* being about 3d. per ton, the refuse, it is claimed, is thus burned, and the residue[1] disposed of at a total cost not exceeding 1s. per ton.

The new destructor is also claimed to give the best results in raising steam for electric lighting or other purposes.

In a report of Messrs. Alabaster, Gatehouse, and Co., upon this destructor as now in use in the yard of the Lewisham Board of Works, Molesworth-street, Lewisham, S.E., it is stated that at the time of their visit the whole of the interior of the revolving cell was found to be in a bright-red condition, and full of refuse and flame. Being about 36ft. in length, the progress of the refuse is of considerable duration; and with such a temperature (at least 2000 deg. Fah.) it is impossible for any gases given off by putrescent matter to escape unburned and unpurified.

Mr. H. Graham Harris, C.E , the Engineer appointed by the Board of Works for the Lewisham District, to examine as to the efficiency of the destructor, reported in November, 1897, that the conditions of the agreement of the manufacturers with the Lewisham Authorities as regards the consumption of the furnace and the absence of nuisance had been satisfied. The words of the agreement on this point were as follows:—(*a*) "That the destructor will cremate from 40 to 50 tons of house refuse per day of 24 hours, and that the formation of clinker from house refuse is impracticable excepting as to residue." (*b*) "That the destructor will destroy all noxious and poisonous gases and smells arising from this refuse while cremating."

MASON'S REFUSE GASIFIER.

Mason's patent continuous refuse gasifier is an apparatus of an entirely novel character for dealing with refuse. It is illustrated in section by the accompanying figure 28, and the following details of the system will be of interest:—In this furnace, instead of burning the gases as they are distilled from the refuse, they are carried into a combustion chamber. Here they are mixed with the necessary amount of heated air to create combustion, with the result that a very high temperature is obtained which can be utilised for raising steam. It is claimed that "1 lb. of water can be evaporated for every pound of good refuse," and the heat obtained is about 1500 deg. Fah. The combustion of the gases being perfect, the nuisance of smoke, smell, dust, and partially-burnt paper is obviated, as well as the cost of a fume cremator.

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[1] The residue or clinker at some destructor works is a source of profit. At Leyton this is sold by contract at the rates of—clinker, 6d. per load; fine ash, 1s. 4d. per load; the contractor undertaking all cartage and labour of removal.

The cells can be built either rectangular or cylindrical. At the base is a water trough, which covers the whole area of the cell, and into which the residue of the consumed refuse falls, from whence it is removed by means of a rake. The water trough also acts as a seal to prevent any gases escaping, and the vapour arising therefrom, together with the steam jet, prevents the grate bars from clinkering up. In the centre of the cell, immediately above the water trough, the grate bars are fixed in a sloping position. Near the top of the cell, on any side most convenient, there is an outlet for conveying the gases into the combustion chamber, and from thence into the flue of the chimney.

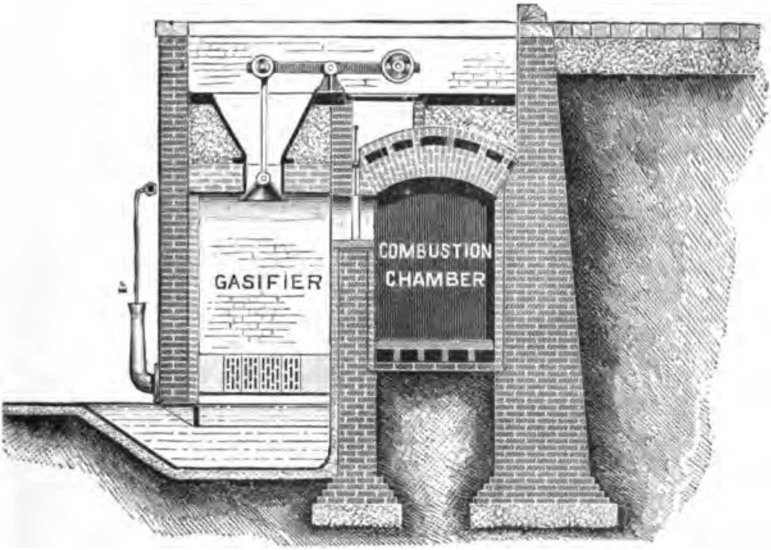

Fig. 28.—Mason's Refuse Gasifier.

The total grate area is 12 square feet, and the manufacturers guarantee to destroy from 5 tons to 8 tons per cell per twenty-four hours.

The refuse is fed into the gasifier by means of a hopper at the top. It falls on to the grate already described, and, after combustion, slides into the water trough below, where it is cooled, ready for taking away. Steam and air are forced under the grate bars to create a draught, so that the cost of a high chimney is, it is claimed, thereby dispensed with. Where it is not intended to utilise the heat generated for steam raising, a small boiler will be necessary to supply steam for forcing the draught. No fuel of any kind is required, except when first lighting a cell. At the week-ends the cells can be banked up with refuse, and started again on Monday morning by merely turning on the steam.

The refuse is reduced to about 25 per cent. of its original bulk, varying, however, according to the percentage of combustible matter contained in it. The slow combustion that is taking place during the distillation of the gases from the refuse reduces the residue to ashes of a suitable character for grinding for mortar making or for use as ballast for roads and footpaths.

As regards the labour required, the constructors state that two men are able to charge six cells and attend to the proper working of them. The total cost of construction, including royalty, may be taken roughly at £200 per cell; this is exclusive of any other work outside the cells proper. Owing to the comparatively low temperature at which the cells are worked, the cost of repairs is said to be small. This system is in use in the district of the Moss Side Urban District Council, near Manchester, where it may be observed that there is no smoke or smell emitted, although the chimney is only 25ft. high. The refuse consists of ashpit refuse, fish offal, and slaughter-house residue.

The patentees and constructors of this Refuse Gasifier are Messrs. W. F. Mason, Limited, engineers, Longsight, Manchester.

CHAPTER VI.

DESTRUCTOR ACCESSORIES.

Jones' Patent Fume Cremator.—This contrivance has been the refuge of many of the earlier destructors, which, being incapable of "consuming their own smoke," have stood seriously in need of some such remedy, inasmuch as public nuisances and legal difficulties have arisen almost simultaneously with their erection. Hence it is that we find the "cremator" forming an essential part of a large proportion of the older destructor installations at the present time.

Not long after the erection of the first destructor in the vicinity of the metropolis, viz., that at Ealing in 1883, complaints of nuisance arose. The vapours given off in the drying of the refuse whilst undergoing its first stage of burning, were very perceptible, and formed cause for complaint; as also did the escape of fine dust, &c., from the chimney shaft. The fact of the existence of a nuisance, it was found, could not be ignored; and, after some consideration, it was concluded that the nature of the furnace was such that the difficulty was only to be overcome by the construction of an *absolutely independent furnace.* This difficulty gave birth to the "fume cremator" in 1885. It was designed by Mr. C. Jones, M.I.C.E., Engineer and Surveyor to the Ealing District Council, who patented the arrangement for the purpose of cremating and rendering harmless the objectionable fumes, known as the empyreumatic vapours, which arise during the earlier stages of the process of burning towns' refuse.

The accompanying figures 29 and 30 show the construction of thefurnace, and it will therefore be unnecessary to give a detailed verbal description. Briefly, the "cremator" consists of a reverberatory arch, with rings of fire-brick placed in the direction of the gases. Ribs of fire-bricks projecting from the arch serve to deflect the gases, and direct them on to the top of a red-hot mass of fire. A heat, varying from 1000 deg. to 1500 deg. Fah., is maintained at a small expense of fuel, fine coke breeze alone, or with the ashes screened from the refuse, being all that is required, together with a supply of air beneath the fire-bars, and a further supply to feed the vapours as they pass into the cremator.[1]

The furnace has from time to time been very favourably reported on by many of those having experience in its use, and also by scientific experts employed to examine as to its utility, but any such appliance obviously betrays the destructor to which it is attached.

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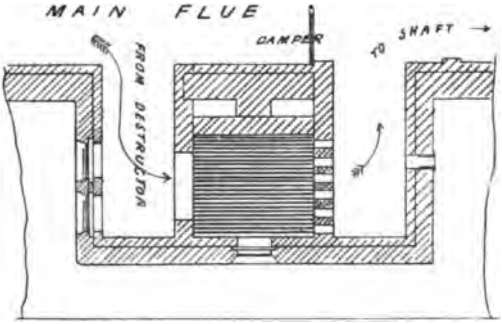
[1] Mr. C. Jones' "Refuse Destructors" (1894).

The fuel used in the cremator is either coke breeze, coke breeze and screened ashes, screened ashes alone, or small coke. The cost of cremating the fumes per ton of refuse destroyed varies from ¼d. per ton, where only cinders are used, to 3¼d. per ton. At Batley, where coke is used, the cost is given at 7d. per ton, and at Nelson, where the destructor was of the "Beehive" type, 3s.

Fig. 29.—Plan of Jones' Fume Cremator.



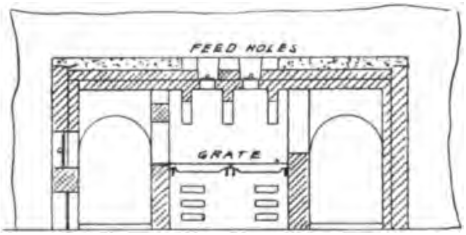


Fig. 30.—Section of Jones' Fume Cremator.

In the discussion which followed the reading of a paper at the Sanitary Institute on "House Dust Refuse," by Mr. J. Russell, in February, 1892, it was stated that with regard to the destructor at Hornsey a *fume cremator* had been added to it, but that it had not been found necessary to use it so long as the firing of the furnace was carefully attended to. The chimney of the destructor was 217ft. high. The cost of using the *cremator* came to about £800 a year,[1] as it was found necessary to use coke for firing. The use of coke breeze had been tried, but caused large volumes of smoke.

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[1] "Transactions" of the Sanitary Institute, vol. xiii, page 57.

Speaking generally of cremators, the following observations[1] of Dr. Stevenson Macadam, Ph.D., F.I.C , &c., appear to be very much to the point. He says: "The difficulties connected with destructors in general for the thorough combustion of the refuse and the escaping gases into innocuous matters, arise mainly from the varying conditions of any single cell from time to time, so that, even when it is possible to get up the proper temperature when the cell is in full blast and in the cindering and clinkering stage, yet, when the charging operations are proceeding, and for some little time thereafter, the temperature becomes lowered below what is required for efficient treatment of the refuse and its products. To overcome the deficiencies, recourse has been had to the use of *cremators*, which practically form part of the main flue, and where a bed of red-hot coke or other fuel is supposed to be constantly burning, and over which the smelling gases must pass and ought to be consumed. The suggestion and construction of these cremators is an admission of the inefficiency of the destructor proper, and are *a mere whitewashing of an imperfect machine.*

"The cremators are costly in working, are not properly attended to, and though I have repeatedly looked at them during my inspection of the destructors, and have even been told beforehand that they were in operation, I have never yet found one of them in actual full work, though otherwise they were in serviceable condition.

"A *cremator* should not be called upon to check or rectify the imperfections of any destructor, and the destructor proper should be capable of doing its own work."

The "Carboniser."—The "Carboniser" was invented by Mr. Fryer for the purpose of converting vegetable refuse into charcoal, but it has not proved a success. It was erected at Leeds, Birmingham, Warrington, and Derby; at which last-named town alone is the furnace still in use, and there only to a very limited extent.

Mr. Codrington gives the following description of the carboniser at Derby:—

It consists of a group of four cells of brickwork, each 2ft. by 8ft. 6in., and 18ft. high, with a vertical flue in the middle, and a furnace alongside each cell at the bottom. Within the cells a series of cast iron plates are fixed with their upper edges touching the walls, and their lower edges standing away, forming a continuous sloping ledge winding round the cell from the top to near the bottom, where they terminate in a fire-brick chamber having a sliding door in the bottom.

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[1] *Journal* of the Society of Chemical Industry, 31st March, 1896.

The refuse is fed in at the top, and is not mobile enough to rise behind the plates, so that a spiral flue is left for the passage of the hot gases from the furnace at the bottom to an opening into the vertical flue at the top and downwards to the chimney.

The refuse dries and sinks coming into contact with hotter plates as it descends until it reaches the red-hot fire-brick chamber. *No air reaches the refuse except through the furnace, and it is therefore charred and not burned.*

At intervals the sliding door in the bottom is opened, and a charge of charcoal is withdrawn. Each cell carbonises about two tons of refuse in twenty-four hours. The furnace burns cinders selected from the ashpit contents. The charcoal is cooled in a revolving cylinder on which a stream of water flows, and is sifted through a screen at the end in a fine powder.

At Derby the carboniser cost £1000; it was worked about two days a week at a cost of £18 per year, and produced about 20 tons of charcoal a year, a ton of vegetable refuse, sawdust, &c., yielding a hundredweight of charcoal, which was used for deodorising, and valued at £5 per ton. This apparatus is now being pulled down for space to erect more destructor cells.

At Leeds no use or market was found for the charcoal, and analysis proved it to contain 80 per cent of earth.

Furnace for Recovery of Tin and Solder from Old Cans.—A small furnace for the recovery of tin and solder from old cans has been introduced by Messrs. Manlove, Alliott, and Co., Limited, The solder tins are collected in hampers or other handy receptacles and tipped directly into the oven. In the course of three or four minutes the solder will be seen running out in a stream through the small aperture and shoot, which lead it into the collecting receiver. When the attendant is satisfied that the whole of the solder has been recovered or run down into the receiver, he moves a handle, which causes the tins to fall on to the lower set of bars, where they are raised to a red heat, and the tin completely burnt off.

The whole process as a rule occupies little more than an hour, and it is found in practice that it may be repeated eight times per day. The fuel is placed on a set of fire-bars near the bottom of the oven, and usually consists of refuse material, such as waste paper, cardboard, hampers, &c., which comes in with the ordinary house and town refuse.

The furnace performs two operations: one, the melting off and collecting of the solder, and the other burning the tin off the iron so as to leave "scrap" of a marketable character. Both processes are carried on at the same time. The economical value of the invention may be gathered from the fact that the solder may be disposed of at prices varying from 5d. to 8d. per pound, and is usually about two-thirds the market value of tin.

Boulnois' and Brodie's Improved Charging Apparatus.—This invention has been successfully introduced as a labour-saving apparatus at the refuse destructor at Liverpool, and other places. It is illustrated in Fig. 31, and is shortly described as follows:—

The invention reduces the manual labour of charging to a minimum, regulates the charge, and lessens the possibility of nuisance or offence.

The apparatus consists of a wrought iron truck, 5ft. in width by 3ft. in depth, and of such length as will cause it to be of sufficient capacity to hold not less than twelve hours' supply for the two cells which it commands. This truck moves along a pair of rails laid across the top of the destructor, and is capable of being worked by one man. The truck is divided into compartments holding a charge in each, and provided with a pair of doors in the bottom opening downwards, which are supported by a series of small wheels running on a central rail. A special feeding opening in the reverberatory arch of the cell of the full width of the truck (5ft.), and placed immediately over the drying hearth, is constructed by a fire-brick arch fitted into a frame capable of being moved backwards and forwards by means of a lever arrangement.

The truck when empty is brought under the tipping platform, and the carts tip their contents directly into it, and when it is required to feed one of the cells the truck is moved along so that one of the divisions is immediately above the feeding opening, and the wheel holding up the bottom doors rests upon the central rail, which is continued over the movable covering arch. Then the movable arch actuated by the lever, is rolled back, releasing the doors and discharging the contents into the cell, so that no handling of the refuse is required from tipping to feeding.

This arrangement provides portable storage for a large quantity of material, and entirely does away with the necessity for the shovelling and handling, which is not only very objectionable from a sanitary point of view, but also adds to the cost of destruction.

Writing upon the charging apparatus as installed at the Liverpool destructors, the City Engineer says,[1] "One of the many advantages claimed for the tank arrangement is that unlimited storage capacity can be provided, which is not the case in any other destructor; and it has been proved that a considerable saving in cost is effected by the introduction of the tanks."

This special form of cell also allows the gases and products of combustion to be drawn off evenly over the level bridge at the back of the cell, instead of at one corner, as in the ordinary Fryer's cell,

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[1] *The Surveyor*, April 9th, 1897.

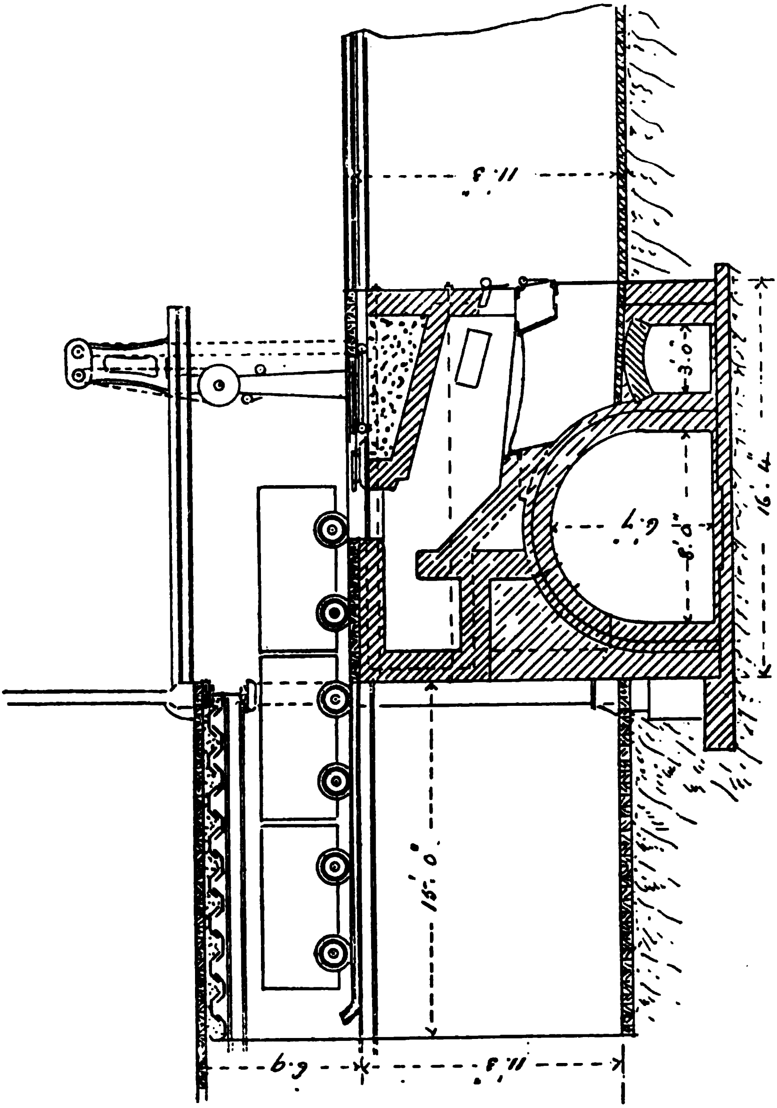

Fig. 31.—Boulnois and Brodie's Improved Charging Apparatus.

and the application of these tanks and movable charging openings can be made to any form of cell now in use.

Fire-bars.—In addition to the ordinary type of stationary fire-bar, there are several kinds of patent movable bars used in connection with destructor furnaces, although these are, as a rule, found to be of but doubtful advantage over the simple stationary type. Amongst the movable bars are the following:—

Settle's Patent Grate Bar[1] is illustrated in Fig. 32, from which it will be seen that a pivot is placed near one edge of each bar, so that they tilt upwards only in one direction, either forwards or backwards, as may be required. The bars are connected to rods, actuated by means of a hand lever, so that the movement of one rod tilts all the even bars and the movement of the other rod tilts all the odd bars. The even and odd bars can therefore be tilted alternately either by hand or automatically.

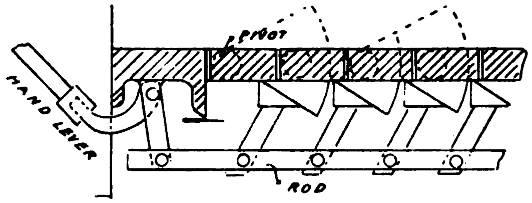

Fig. 32.—Settle's Patent Grate Bar.

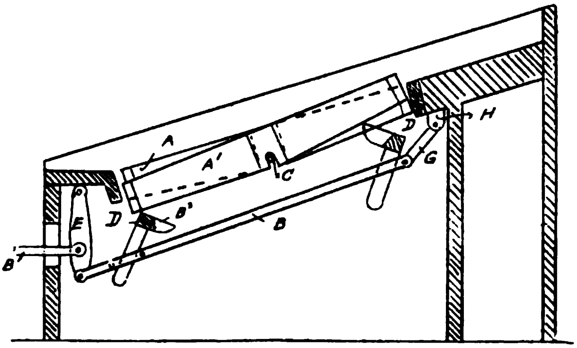

Fig. 33.—Biddle's Rocking Bars.

Each bar when tilted throws its fuel on to the next bar in succession, and, as the odd and even bars work alternately, whilst the intermediate bars remain stationary, the bars act as "carriers" as well as "rockers," and thus convey the clinkers and fuel either towards the bridge or towards the furnace doors as may be required, according to whether the bars are fixed with the pivots to the back edge or to the front. In the former case fuel fed on to the bars nearest the dead-plate will be gradually carried towards the bridge.

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[1] Patent No. 15,482 (1885).

Vicars' Grate Bars[1] impart a forward motion to the fuel or refuse, and are actuated by machinery from a cam shaft.

Biddle's Rocking Bars,[2] Fig. 33. The fire-grate consists of a series of bars, of which each alternate one is made to rock as shown in the diagram. A, stationary bar; A^1, rocking bar; C, a transverse rod upon which A and A^1 take a bearing centrally. The stationary bars A at each end take a bearing on the stops or lugs D, whilst the rocking bars can be moved at and through varying speeds and spaces. The bars are actuated by means of a lever B^1, connected through link E to the inclined rod B bearing the member B^2, which acts upon the bars as shown.

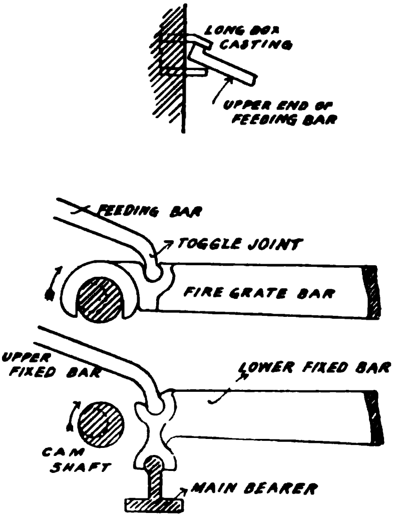

Fig. 34.—Healey's Movable Bars.

Horsfall's Self-feeding Apparatus.[3] — In one of Horsfall's "improved type" furnaces, at the bottom of the refuse hopper, there is a series of sliding plates, or "pushers," adapted to force the refuse forward on to the grate bars, which are of the moving or rocking type; and are usually constructed according to Settle's patent. The "pushers" extend the whole width of the furnace, and they are operated by means of eccentrics through eccentric straps and rods, the shaft on which the said eccentrics are mounted being rotated slowly from any suitable source of power. On the same shaft are also mounted cams, adapted to operate levers actuating the moving or rocking grate bars, through suitable links or rods. By the use of these pushers and moving or rocking grate bars, the refuse and clinker are gradually moved forward, so that the ashes and clinker are deposited on the front dead plate, from which they are removed at intervals through the furnace door.

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[1] Patents No. 1955 (1867), and No. 378 (1879).
[2] Patent No 4896 (1891).
[3] Patent No. 20,207 (1892).

Healey's Movable Bars.[1]—These are forwarding motion bars, fixed as shown in the illustration of Healey's furnace (Fig. 11), and are constructed as illustrated in the accompanying diagram (Fig. 34). Above the fire-grate bars, which are fixed level, are small inclined feeding bars, the feet of which take their bearings in toggle or knuckle joints on the fire-grate bars. At the upper end of the inclined bars is a long box casting or carrier, in which the upper or fixed feed bars can expand, and the moving feed bars can reciprocate.

Healey's feeding and fire-grate gear is applicable to all kinds of furnaces in which refuse fuel is burnt, and his patent extends to the gearing of the motor[2] which drives the cam shaft for operating the bars.

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[1] Patent No. 18,898 (1892).

[2] Healey's motor for bars, Patent No. 12,990 (1892).

CHAPTER VII.

GENERAL OBSERVATIONS ON REFUSE DESTRUCTORS.

Cost of Construction.—In regard to the initial cost of the erection of Refuse Destructors very little reliable data can be given, as the circumstances of no two cases are, as a rule, even approximately similar. The outlay will necessarily be dependent, amongst other things, upon the difficulty or otherwise of the preparation of the site, upon the nature of the foundations required, the height of the chimney shaft, the length of the inclined or approach roadway, and also upon the varying prices of labour and materials in different localities.

Information derived from "returns" of the costs of erection at various towns is of but little practical value, and, for all purposes, must be accepted with the greatest caution, as it is impossible to make useful comparisons between the costs of erection at various places without knowing the circumstances of each. Incidental works, such as boundary fences, special foundations due to bad ground, extra tall chimney shaft, mortar mills, engines, &c., may be included in the one case and not in another.

These differences will be apparent from an inspection of the table on the next page, which gives the approximate initial outlays for the destructors at the places mentioned.

From the figures given it will be seen that the average cost of construction, including the usual accessories, but exclusive of site, at the towns named is about £840 per cell, and the average height of shaft is 158ft.

At Bristol the total cost of a 16-cell destructor was £11,418, of which £2909 was expended in foundations, and £1689 for the chimney shaft, thus leaving £6820 for cost of destructor, buildings, and approach road, or about £426 per cell.

The following averages of returns from thirty-five towns obtained by Mr. Price (whilst surveyor of Toxteth Park) are given by Mr. Boulnois,[1] and will be of interest:—

Average cost of construction of destructors = £525 per cell.

Cost of chimney to erect = £6 3s. 4d. per foot of height.

Height of chimney = 163ft.

Number of tons consumed per diem per cell = 6 tons.

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[1] "Municipal Engineers' Handbook."

Number of men employed per cell = 1·17.

Cost of destruction of refuse = 11½d. per ton.

Annual cost per cell = £96.

Cost per ton of burning refuse.—The cost per ton of cremating refuse in destructors will depend chiefly upon:—

(1) The type of furnace adopted.

(2) The price of labour in the locality, and the number of "shifts" per day.

Initial Cost of Destructors.

Town.	No. of cells.	Height of shaft in feet.	Initial outlay, exclusive of site.	Cost p. ton of burning refuse, exclusive of interest on cost of works.	
			£	s.	d.
Battersea	12	180	12,000	2	10
Bootle	12	170	9,200	0	10½
Bournemouth ...	6	140	3,171	0	9
Bradford	12	180	10,250	0	6
Brighton	12	225	16,679	1	7
Burton-on-Trent ...	8	144	4,266	1	7¼
Buxton	4	150	1,315	0	8
Cheltenham ...	8	160	6,000	0	7½
Govan	8	120	6,346	1	6½
Hastings	4	130	4,000	1	6¾
Hull	6	180	3,200	0	11
Leicester	6	160	6,694	0	8
Leicester	6	180	8,069	0	8
Leicester	6	180	8,852	0	8
Leyton	8	150	6,000	1	3*
London (City) ...	10	150	13,311	1	8½
Liverpool (Charters street)	24	170	11,488	0	9
Oldham	10	120	4,527	0	9¾
Rotherham... ...	6	130	4,000	1	2½
Sheffield	6	180	9,500	—	
Sowerby Bridge ...	2	140	1,829	1	2
Stafford	4	135	2,315	0	9
Whitechapel ...	16	180	10,500	1	1
Withington ...	6	150	6,600	0	8

* Pressed sewage sludge is mixed with refuse and burnt.

(3) The nature of the material to be consumed.

(4) Interest on and repayment of capital outlay.

In many towns the gross cost can often be materially reduced by the sale of clinker, fine ash, mortar, &c.; also by the profitable application of the heat generated for raising steam for any work for which it may be required, such as driving sewage works machinery, pumping, or for electric lighting.

As a result of returns from forty-six towns, collected and published in 1894 by Mr. C. Jones, M. Inst. C.E., it was found that the expense

Table showing Relative Cost of Labour per Ton of Refuse Burnt.

Name of city or borough.	Type of destructor.	No. of men to be employed.	No. of shifts per day.	Rate of wages per week. s	No. of cells.	Tons per day per cell.	Days per week worked.	Cost in wages per week. £ s.	Tons of refuse per week.	Cost per ton destroyed. d.
Oldham	Horsfall's	6	3	30	6	7	5¼	9 0	221	9¾
Royton	Warner's	3	3	30	3	5	5¼	4 10	79	12⅛
Leeds	Horsfall's	12	3	30	12	7	5¼	13 0	441	8¾
Bradford	Fryer's[1]	12	3	30	12	7	5¼	13 0	441	9¾
Warrington	Beaman and Deas'	6	3	30	2	18	5¼	9 0	189	11½
Toxteth Park	Fryer and Boulnois'	7½	3	30	6	7	5¼	11 15	221	12¾
Liverpool	Fryer and Boulnois'	16	3	30	12	8	5¼	21 0	504	12¾
Liverpool	Fryer's	23	3	30	10 2	7 8½	5¼	33 15	457	17¾
Dewsbury	Beaman and Deas'	6	3	30	2	15	5¼	9 0	158	13¾

[1] Fitted with forced draught.

(exclusive of interest and sinking fund on cost of works) incurred in destroying refuse is represented as varying from 8½d. to 1s. 7d. per ton; and about 10d. per ton is considered a fair average.

The average cost of burning refuse at the towns named in the above table, which is compiled from information kindly supplied to me by the Borough Engineers and Surveyors at the places mentioned, is 1s. 1½d.

Mr. Jones also says that the cost of *cremating fumes, &c.*, per ton of refuse destroyed varies from ¼d. per ton where only cinders are used to 3¼d. per ton at Ealing. At Batley, where coke at 10s. 2d. per ton is used, the cost is as high as 7d.

In an interesting report on refuse destructors prepared in June, 1896, by the Borough Surveyor of Ashton-under-Lyne is the table on next page, showing the relative cost—per ton burnt—in stoker's wages, when *all towns are put upon the same ratio with regard to rate of wages, number of hours per day, and days worked per week.* The basis adopted is an eight-hours shift, 5½ days per week, and a rate of pay of 30s. per week per man.

The value of Town Refuse for Power Production.—The generation of steam by the utilisation of the waste heat of a destructor, although an important asset in connection with such work, should not be pursued as a matter of first importance so as to in any way impair the efficient performance by the furnace of its primary functions as a *refuse destructor.* The proper course, doubtless, is to make the destructor as perfect as possible *as such*, afterwards passing the gases (subsequent to their having fully performed their work in the furnace) through a suitable boiler, and taking the result for what it may then prove to be worth, which in high-temperature destructors is found to be sufficient to effect a considerable saving when steam power is required for pumping, lighting, or any other work.

The primary considerations requisite for a perfect destructor include the following[1]:—

(1) The temperature attained should be sufficiently high.

(2) The duration of exposure to a high temperature should be sufficiently long.

(3) *All* the vapour escaping from the refuse should be heated to a sufficient extent, and there should be no possibility of the escape of any undecomposed vapours into the chimney shaft.

The first requirement implies the use of a forced draught, and the second indicates the impossibility of placing boilers over the hottest part of the furnace, so as to enable them to best utilise the full calorific value of the burning refuse, as the temperature of the furnace would be materially reduced by placing a large mass of comparatively cold water directly over the fire. It should therefore be borne in mind when comparing the evaporative value of towns' refuse with that of coal as used in connection with boilers, that the former cannot be utilised under similar conditions to the latter without impairing the value of the destructor.

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[1] Report on "Dust Destructors," London County Council, May, 1898.

In regard to the theoretical calorific value of refuse burnt under the most advantageous conditions for purposes of steam production, Professor Forbes, in his Cantor Lectures before the Society of Arts, 1892, said, "Now it will strike you, as it has struck me, as a very wise provision of Nature, when I tell you that *if* that refuse (at Paddington) were *properly burned*, and *if* it were *used in the most economical way*, it would be found that (assuming the proportion of lighting required for such a population to be, as has been very generally assumed, one lamp per head[1]) the amount of refuse provided by any population is almost exactly as much as is required to supply the illumination by means of the electric light to that same population."

In actual destructor practice, however, refuse is not burned under the favourable conditions assumed above, and the practically attained results do not reach anything like the theoretical estimate.

Mr. J. Tomlinson, B.E., A.M.I.C.E., has deduced, from results experienced at various destructor installations throughout the country, the following statement of the power available for external work, put in each case in the form of I.H.P. continuously per cell, consuming six tons per day of twenty-four hours:—

Batley	8½	I.H.P.	Hastings	5	I.H.P.
Birmingham	50	,,	Hastings (with cremator)	10	,,
Blackburn	5½	,,	Liverpool	4	,,
Bury	3	,,	Southampton...	4	,,
Ealing	4	,,	Warrington	8½	,,

The high result obtained at Birmingham, where from several tests it appeared that 1 lb. of refuse evaporated 1·79 lb. of water, is explained by the fact that "it was necessary there to keep up steam for the treatment of the excreta, and steam was got up from these furnaces *by putting the boilers directly over the furnace*. In consequence of this, the combustion is extremely imperfect. The large cooling surface of the boilers impedes the combus tion in an effectual degree. In most cases where boilers have been used to generate some steam, the boilers have been put away, and after the gases have passed through the flue they then pass by the boiler, and the error has been in the opposite direction."

In a report on the proposed electric lighting for the borough of

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[1] One 8-candle power lamp per head for two hours for every night of the year.

Ipswich in regard to the question of a combined destructor and electric light station, Professor Kennedy observes that "it is very easy to overestimate the saving in fuel which can be effected by combining an electric light station with a destructor, yet there is no doubt that some economy will result from the combination, and this is a point which is worth while keeping in mind." Upon the same point the borough engineer, in his report[1] on town refuse destructors, expresses the opinion that whatever the available power for electric lighting may be, it could not be constant owing to necessary stoppages for repairs and other purposes; therefore, an electric light installation, if designed in connection with a destructor, should be complete in itself, but at the same time so arranged that it could take advantage of the heat when available.

Mr. Druitt Halpin has recently introduced a patent process of storing surplus heat, the object of the invention being, instead of generating electricity and adopting expensive storage, to store the power which produces the current; the basis of the system being the storage of heated water under pressure in "reservoirs from which steam is taken, through a pressure-reducing valve, when and how required." Halpin's system has been installed at the Shoreditch Destructor and Electric Light Works, and is said to be especially applicable where heat is used from a refuse destructor.

The surplus heat of destructors has been applied not only to purposes of electric lighting, but also to driving mixing machinery at sewage disposal works, air compressing for sewage sludge plant, driving mortar mills, lifts, chaff cutting, pumping water, &c. At Eastbourne the boiler power required for operating the air-compressing engines, in connection with the "Shone" system of drainage, is supplemented by this means.

The relative value of town refuse and furnace coal, as steam producers, has been variously stated. Practical results, of course, depend upon the quality of the refuse and the conditions under which it is burned. Average refuse is frequently stated at about one-tenth the value of good furnace coal; but at Birmingham, where multitubular boilers are set in such a manner as to form the top of the furnace, it is found in practice that 1 lb. of refuse will evaporate 1·79 lb. of water; that is to say, that as a steam producer the refuse is about one-fifth the value of an equal weight of coal.[2]

Duty per Cell.—The quantity of house refuse destroyed per cell per day varies from 8½ tons up to 10 tons, and in the Beaman and Deas' furnace from 20 to 24 tons per cell per day. Much depends, however, upon the care or the reverse in stoking, upon the class of material, and the frequency of removal of clinker; also upon the question as to whether the whole of the refuse passed into the furnace is thoroughly cremated.

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[1] March 16th, 1896.

[2] Report on "Dust Destructors." (L.C.C., May 10th, 1892.)

Great attention is now being directed to the utilisation of the surplus heat derived from the combustion of refuse, and in many towns, such, for example, as Cambridge, Shoreditch, and Hereford, the main object aimed at is not the riddance of the largest quantity of refuse possible per cell, but the full utilisation of all the heat available from this class of fuel—provided the material is properly burnt and without trace of nuisance.

Amount of Residuum, and its Uses.—The amount of residuum, in the shape of clinker and fine ash, varies from 22 to 37 per cent. of the bulk dealt with. About 25 per cent. is a very usual amount.

The clinker is found to be useful for mortar making, is ground with lime in a pug mill, and, in some towns where there is a demand, is sold at a profit. It has also been applied to the manufacture of paving slabs, &c., and is a very useful material for bottoming roads carrying a light traffic. Where there is no demand, and where the above uses do not arise, it is found to be expensive and difficult to dispose of.

At the Battersea destructor depôt, during the year from 25th March, 1896, to 25th March, 1897, it appears that 2060 tons of clinker were carted away by contractor, 1989 tons given away at the works, and 1658 tons were used by the Vestry. A considerable amount of the residue is utilised in the manufacture of tar and concrete paving, a large quantity of which has been used in paving the footpaths of new streets and other paths in the parish, or sold to contractors and adjoining parishes. During the same year the removal of old tins and fine ash entailed an expenditure of £127 2s. 4d., whilst the cash received for clinker was £24 8s. 1d.

Of the total residue arising from the working of an ordinary refuse destructor it is found 8 per cent. to 9 per cent. consists of "*fine ash,*" and 17 per cent. to 18 per cent. of "*clinker.*" These amounts vary somewhat in almost every town, and depend upon:—

(*a*) The habits of the people, and the method and frequency of dust collection.

(*b*) The time of the year, and the state of the weather.

(*c*) The quantity of "trade refuse" dealt with.

(*d*) The locality of the town, and the amount of coal used in domestic fires.

(*e*) The proportion of vegetable refuse.

(*f*) The temperature of the furnaces, or whether forced draught is in use.

As this residuum amounts to from one-fourth to one-third of the total bulk of the refuse dealt with, it is a question of the utmost importance that some profitable, or at least inexpensive, means should be devised for its regular disposal. The following are among the many uses to which it has been put:—

(*a*) Forming bottoming for macadamised roads.

(*b*) Crushing to suitable size, and mixing with Portland cement for making concrete, which may be applied to any of the uses to which concrete is usually applied.

(*c*) Crushing to small size, mixing with cement for making paving slabs.

(*d*) Breaking and sifting and mixing with fine ash for use upon suburban footpaths, or cinder footwalks.

(*e*) The fine ash may be used as a cushion bed for paving sets.

(*f*) Mixing clinker with lime, placing in a pug mill with water for the manufacture of mortar. This is a very general, and in many places profitable, mode of disposal.

(*g*) The fine ash has been suggested as a suitable base for the manufacture of carbolic powder.

(*h*) In some cases, for want of a better mode of disposal, it is used for filling in old quarries, gravel holes, pits, or other depressions in the suburbs of the town.

(*i*) There are also instances where it has to be barged away or sent to sea in steam hopper barges, and discharged in deep water. This is done at Liverpool, the cost of disposal being 2s. per ton.

(*j*) The ashes have been used for mixing with heavy clay soil on sewage farms.

(*k*) It has also been suggested that the ashes would improve the quality of ordinary bricks if mixed with brick-earth and clay.

Manufacture of Flagging for Footpaths.—In the manufacture of flagging for footpaths the clinker may be broken to suitable sizes, and made into Portland cement concrete, and laid *in sitú* upon the footwalk about 3in. or 4in. in thickness, and trowelled up to a face. In order to prevent upheaval and cracking, the disastrous effects of which may oftentimes be observed in monolithic concrete footpaths of large unbroken area, the concrete should be laid in alternate bays of not more than 6ft. in width.

Paving Slabs.—Sometimes the clinker concrete, made in the ordinary manner, is placed in iron-lined moulds of suitable dimensions, and rammed by hand punners into the moulds. When the concrete is sufficiently set, the sides of the mould are removed, and the slabs stacked until they are sufficiently hard to lay upon the paths. This is usually from six to nine months after manufacture. The appearance of the flag is somewhat against it, but in Liverpool this has been improved by painting the surface with a fairly strong mixture of Portland cement and water, which has had the effect of brightening the surface and of filling in the interstices in the flags. In Southampton and elsewhere the crockery is taken from the refuse, smashed up, and used for facing the slabs, which, by a slight stretch of courtesy, is considered by some to give them a pleasing mosaic appearance. In speaking upon the durability of this class of slab, Mr. J. Price (Birmingham) has given it as his experience that after twelve years there has not been more than about ⅛in. wear on flagging in crowded thoroughfares.

Mr. H. Percy Boulnois, M. Inst. C.E., when city engineer of Liverpool, introduced a method of making clinker concrete flags under hydraulic pressure, and has given the following description of the process of manufacture :—[1]

"The plant, which has been patented by Messrs. Musker, of Liverpool, consists of a hydraulic press or 'ram,' the pressure for which is obtained from the Liverpool Hydraulic Power Company, who give a pressure in their mains of 750 lb. on the square inch, which is used for the moving operations; but for the final pressure an 'intensifier' has been introduced between the main and the press, which raise this pressure so that the final pressing operations reach a pressure of 2¼ tons on the square inch. The clinker is broken in a small crusher worked by the engine supplied with steam by the destructor, to about ⅜in. size, and this is mixed by hand on an ordinary bunker in the proportion of one part of cement to three parts of broken clinker, the compo being mixed very wet.

"The frame in which the mould is placed works in a horizontal direction, upon the rails supporting the frame, by hydraulic pressure, and the mould is filled with the compo when it is outside the press, a pad being placed at the bottom of the mould, composed of a perforated zinc plate covered with thick insertions. When the man (who is filling) has screeded off the top of the mould, he places a felt pad over the mould, pulls a lever, and the frame passes into and under the head of the press. By means of another lever he raises the mould and frame right under the fixed head of the press, and by a third movement he brings the whole pressure from the ram directly upon the slab.

"This pressure is allowed to continue for about a minute, when water from the compo ceases to flow, and it may be observed that owing to the pads no cement comes out with this water. The pressure is then relieved, the frame is allowed to drop, and then withdrawn by hydraulic pressure outside the press.

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[1] "The Disposal or Utilisation of the Residue from Towns' Refuse Destructors;" paper read before a meeting of Municipal Engineers at Brighton, June, 1896.

"Underneath, and level with the ground, a movable platform is provided, which is worked vertically by hydraulic pressure. Upon this platform a small trolley is run, having had previously placed upon it a movable flat board provided with handles, and upon this board the slab is received. In the meantime the frame containing the mould and slab is turned over and the platform lifted, which brings the flat board already referred to close up under the slab, and by turning a handle the nuts pressing against the heavy false bottom, or die at the bottom of the mould, are slackened, which then falls and pushes out the slab in the mould; and consequently, when the platform is lowered the slab comes out with it, and is wheeled off on the trolley, and carried on the flat board in question by two men to a suitable position, where the slab is allowed to ripen for a couple of days, and is then up-ended.

"The number of men employed is as follows:—A lad works the lever handles, fills in and screens the compo in the mould, and three men manufacture the concrete and pack the slabs. About 45 yards of slabs are manufactured per diem, the cost being as follows:—

Cost of manufacture of one yard of clinker concrete flagging, 2½in. thick.

Material.	Cost.
*65 lb. of Portland cement	10¾d.
†152 lb. of clinker	nil.
‡Water	¼d.
Labour	5½d.
Plant, contingencies, and supervision	3¼d.
Total cost per yard	1s. 7¾d.

* Varies with cost of cement. † Really a saving of 1¾d.

‡ This item could be dispensed with where pressure is obtained by using steam-power of destructor.

"The total cost of manufacture is thus about 1s. 7¾d. per square yard, without reckoning the saving in using the clinkers. The sizes of the slabs that are made are 2ft. by 2ft., 2½ft. by 2ft., and 3ft. by 2ft., each being 2½in. in thickness.

"Some of these slabs have been laid twelve months and show no sign of wear, but sufficient time has not yet elapsed to say whether they will last as long as Yorkshire or other natural stones; but from the experience already gained it would appear that this class of flag will have a life as long, if not longer, than Yorkshire flags, and owing to the porous material with which they are made, the clinker-paving slabs have a foothold much better than the natural stones. Their colour is rather dark, but this slight objection may be obviated by painting the flags, after they have been laid, with a mixture of cement and water, which takes some time to wear off.

"The following table gives some tests of these slabs which have been made, and when the youthful age of the slabs is taken into account, they may be considered very satisfactory:—

Tests of machine-made clinker concrete flags, 2½in. in thickness.

Age of flag. Months.	Breaking load applied at centre of flag. lb.
4	1804
4	1474
4	1742
4	1917
4	1608
4	1752
6	2061
6	1966
4	1859
4	1659
4	1589

"The total cost of the machinery as supplied and fixed by Messrs. Musker was £1275, the foundations and necessary plant cost £225, exclusive of the clinker crusher, which cost £45, making a total for the whole installation of £1545."

In connection with the above process the Adamant Stone Co., Ltd., in 1896, brought an action against the Liverpool Corporation for an alleged infringement of their patents of 1884 and 1893. The 1884 patent appears to have been for making slabs out of Parian, Keen's, or other cements in a porous mould under pressure; and that of 1893 for using for a similar purpose clinker broken to the size of small shot. The claim for the 1893 patent was dismissed with costs, but in regard to the 1884 patent it was held that the claim was good, and that it had been infringed, and, consequently, on this count judgment was given for the plaintiffs, with costs. Commenting upon this case, the *Surveyor* (December 11th, 1896) says:—"The effect of the judgment appears to us to be that municipal engineers need be under no apprehension that the mixing with cement of clinker (even when the latter is broken to the size of small shot), and the subsequent subjecting of the mixture to pressure, is an infringement of any existing patent. But—and the limitation is one it would be as well to note carefully—if this pressure is effected in a *porous* mould the process is an infringement of the 1884 patent of the Adamant Stone Company. Moreover, it is also worth noting that, in the ordinary course, the company's patent can only run for two more years."

The defendants appealed, but ultimately it was ordered to stand over until the adjournment, with a view to a settlement. The appeal was then withdrawn, in accordance with an arrangement between the parties, the terms of which did not transpire.[1]

In regard to the utilisation of the residue from destructors, Mr. N. Blair, M. Inst. C.E., of St. Pancras, said, at a meeting of municipal engineers at Brighton (June, 1896),[2] as his Vestry had to pay for the removal of this residue, he had endeavoured to find other methods of treating fine ash and clinker, and to show whether it would compare favourably with other material he made briquettes of cement composition, using in some of the most suitable clean sand, and compared them with cement briquettes made of fine ash or of crushed clinker. One might naturally expect to find that the selected sand would give better results than the briquettes made of this composition from the fine ash, and he was surprised to find that it was otherwise. The result upon briquettes of 1 square inch section, in which the proportion was 3 to 1 of fine ash and cement, at three months was 204 lb. breaking strain, and in the case of the briquette made of the best sand obtainable for the purpose, 179·5 lb. The ordinary Thames sand, which is very largely used in London, dropped down to about 46 lb.; so that the cement composition made of the fine ash of the destructor furnace proved better than that made from the best sand obtainable. It was the same with concrete. He had some concrete blocks made for testing purposes. The first lot of blocks — 12in. cubes — were mixed 5 to 1. The blocks made of clinker taken from the furnace mouth, containing tins and all classes of fine material, mixed in the proportion of 5 to 1 with cement, broke at the age of three months under a crushing weight of 55·6 tons. Rough Thames ballast containing stone from 2in. diameter down to sand, mixed in the same proportions and at the same age, broke at 45·2 tons, and fine Thames ballast containing pebbles from ¾in. down to sand broke at 23·7 tons, so that in this case also the concrete made of clinker, just as it came from the furnace mouth—not selected, not even riddled—gave the best results.

Mr. Blair has also attempted to convert the fine dust into carbolic powder. A sample was examined by a firm of manufacturers, who reported that they thought it was very suitable, and offered to make carbolic powder from the dust, employing the same proportion of acid as in the ordinary 15 per cent. powder. This they could sell at 25s. per ton less than the ordinary powder of commerce.

Mr. J. H. Cox, M. Inst. C.E., of Bradford, has had destructor flue dust analysed, and found there was very little nitrogenous matter in it—in fact, it was not worth naming as to its value for manurial purposes. It was only ·023 per cent., but the analyst said it might be useful to manure manufacturers for some of their preparations which require an absorbent.

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[1] The *Surveyor*, March 12th, 1897.

[2] "Proceedings" of the Association of Municipal and County Engineers, vol. xxii.

At one depôt in Bradford there are twelve cells, burning 24,000 loads in a year, producing approximately 6000 loads of clinker, 2000 loads of which are made into mortar. Being in a flag-stone district, the question of providing machinery for slab making has not been fully gone into; but a good outlet for the material has been found in putting up crushing and screening machinery. The clinker is crushed and screened into various sizes, and is proposed to be used for making common asphalt by mixing with pitch and tar, and using on the suburban foot-walks.[1]

The Question of Alleged Nuisance from Destructors.—Owing to defects both in the design and management of many of the early destructors, complaints of nuisance have frequently arisen, and have thereby brought all refuse destructor installations, both ancient and modern, into popular disrepute. When it becomes known that it is intended to erect a destructor upon any given site in a town, the case of its efficiency or otherwise is invariably prejudged, and numerous objections on the ground of its being a source of nuisance are at once conjured up by popular prejudice. It cannot be denied, however, that some of the old furnaces have been decided offenders in the direction indicated; but such is not the case with the modern improved type of high-temperature furnace, and oftentimes, were it not for the great prominence in the landscape of a tall chimney shaft, the existence of a refuse destructor in a neighbourhood would not be generally known by the inhabitants. At the present time there is no reason whatever why a destructor, properly designed and managed, should be a source of the slightest nuisance.

The nearness of inhabited houses to a destructor is not a matter of any great significance in regard to the question of the satisfactory working of the furnaces, as where there is a shaft of average height experience shows that when complaints of nuisance have been made, they usually originate from inhabitants who live some considerable distance from the site of the works, and especially from those residing in portions of the district approximately on a level with the top of the chimney shaft.

In the course of the inquiries made by the Engineer and Medical Officer of the London County Council, in connection with their joint report on "Dust Destructors," these officers, in several instances, were informed that there was much local opposition to the establishment of a destructor when the scheme was in contemplation, and in some cases complaints of dust and smoke seem to have come to hand before any refuse was burnt in the furnaces.

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[1] "Proceedings" of the Association of Municipal and County Engineers, vol. xxii.

It is a much more difficult matter than might at first sight appear to localise and trace to its source a given nuisance, and it is quite possible that in some instances the destructor has been accused of producing a smell which was really attributable to some other cause. The manager of a gas factory who complained that the neighbouring destructor brought the gasworks into discredit is certainly to be complimented on his ingenuity.

Any nuisances which may arise from destructor dust or pieces of charred paper are of a much more unmistakeable character than that of smells, as will be shown later, and, where these occur, must constitute a serious charge against the destructors concerned.

The use of forced draught, either by dry air or steam jets, is an effective means of preventing nuisance, and substantially increases the temperature of the furnace. Dr. Cameron writes in regard to the results of experiments carried out at one of the Leeds destructors that "the observed temperatures with the jets were 346 deg. Fah. above those without; but taking into account the fact that upon seventeen occasions in the one case against three in the other the temperature was too high to be registered, the real difference would be nearer 500 deg. Fah."

Out of forty-three towns included in the inquiries of the Borough Engineer of Ipswich, for the purposes of his report[1] on "Town Refuse Destructors," it appears that nineteen have on certain occasions had complaints of nuisances arising from the burning of refuse which seem to have arisen from the escape of fine dust, small particles of burnt paper, and occasional smells, with the wind in a certain direction. These have been remedied by a screen fixed in the flue to intercept paper and fine dust, and the unconsumed gases destroyed by the application either of the Jones' cremator, which is fixed between the furnaces and the chimney, and maintained at a high temperature, or by steam jets for effecting the same end.

The Vestry of Paddington, in 1895, undertook investigations upon the destructor question, and, as the result of their inquiries, which extended to some thirty installations in various parts of the country, they conclude generally that the creation of nuisance in the process of burning is avoidable, and must be attributed to improper working of the destructor rather than to defects in the system. The nuisances that have been alleged to occur are dust from the tipping sheds and smoke shaft, and fumes from the furnaces and shaft. The scattering of dust from tipping sheds, they consider, can be obviated by the construction of suitably designed buildings, and dust and fumes from the shaft are due to insufficient length of flues or to over-working of the apparatus. Some smell has also arisen from the practice of cooling with a jet of water the hot clinker drawn from the furnace; but this can be done in a manner that will not permit the fumes to escape anywhere but up the flues.

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[1] March 16th, 1896.

Some instructive information upon the question of "Destructor Smells and Dust" has been given by Mr. Stevenson Macadam, Ph.D., F.I.C., &c., in the "Journal"[1] of the Society of Chemical Industry, in which he says:—

> Smells may arise (1) from the tipping or charging shed, where the materials are emptied out of the carts, and are often spread more or less over the tops of the furnaces, where they are subjected to much heat and undergo a process of drying and stewing, with the result that vapours with a "singed-like destructor odour" are markedly observable, and which are distinctly noticeable in the atmosphere of the neighbourhood to the leeward of the destructor. In high winds even semi-consumed dirty papers may be blown about and fall in neighbouring properties.
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> (2) From the furnace vaults or drawing chambers, where the material is dragged out or raked out of the cells in a more or less imperfectly burned state, with the result of the disengagement of volumes of vapours with the singed-like destructor smell, accompanied and succeeded by sulphurous anhydride, and in places where water is used for quenching the red-hot *débris* the sulphurous anhydride is succeeded by sulphuretted hydrogen. Placing oneself in the line or track of the wind, the respective smells may be clearly observable at a distance of hundreds of yards from the destructor. A hypothesis has been suggested that the sulphur compounds, viz., sulphurous anhydride and sulphuretted hydrogen may neutralise each other, but practically they cannot do so, as the first has the start of the second, and a gentle wind of the velocity of 3½ miles an hour will sweep on the sulphurous anhydride at the rate of 5ft. in the second or 100 yards in a minute, and such column of polluted air containing sulphurous anhydride will precede a second column (when the water has been added) where sulphuretted hydrogen is present, notwithstanding the difference in density or the respective rates of diffusion of the gases. The practical result, therefore, is that the two sulphur gases can be distinctly observed in the atmosphere of the neighbourhood, even by the sense of smell, and no doubt they exert their respective deleterious actions on plant life, and more or less affect the vitality of the shrubs and other vegetation.
>
> (3) From the chimney head due to the imperfect combustion of the organic matter and vapours in the cells and flues. No doubt a good height of chimney, 180ft. or more, will tend to distribute the fumes more widely throughout the atmosphere, but in a badly-constructed or worked destructor, where the temperature is too low for the perfect and complete combustion of the fumes, there will necessarily be evolved from the chimney head a decided fœtid singed odour which may be shortly stated as "the destructor smell." The escape of such foul gases from the chimney head depends much on the temperature of the cells, service flues, and main flue. We cannot be satisfied with a temperature less than that of a cherry-red heat—1500 deg. to 1600 deg. Fah. in the flues—and even the higher temperature of a yellow-red or orange—about 2000 deg. Fah.—may be held to be advantageous. Anything like a black-red heat—about 1000 deg. Fah.—must be regarded as of little service for the complete combustion destruction of organic melling gases.

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[1] March 31st, 1896.

The dusts must also be included as main factors in any nuisance from the operations of an inefficient or badly-worked destructor. These dusts may arise (*a*) from the charging sheds where the town garbage is thrown down from the carts, (*b*) from the furnace vaults during the drawing or discharging of the cells, and (*c*) from the vaults where water is thrown upon the hot *débris*, either by buckets or fire hose. In the latter case the clouds of steam are accompanied by much fine dust in suspension.

As a preliminary to the investigation of the destructor dust and its identification from ordinary road dust and even railway dust, when the destructor is placed in the immediate neighbourhood of railway lines, it is advisable to separate the coarser particles from the real fine dust, and that without any attempt to pulverise or reduce the larger pieces. This is most readily done by sifting the dust through sieves, and the trials made by me showed that a wire-gauze sieve with 1600 meshes to the square inch—being 40 by 40—only kept back paper ash and loading, small stones, cinders, &c., and the real dust which was liable to be blown about readily passed through the meshes. Indeed, part of this fine dust would pass through a sieve with 6000 meshes to the square inch. The proportions of 1600 meshes to the square inch were found mostsuitable for working with all sorts of dust, whether destructor dust, road dust, railway dust, or field dust.

The identification of destructor dust may be carried out partly by chemical and partly by microscopic means. Firstly, it is found that when the dust is diffused through the atmosphere by sifting it through the fine sieve in front of the nose, the peculiar singed-like fœtid odour characteristic of the destructor smell, is distinctly observed, exactly similar to that noticeable in the drawing vaults of the destructor. The same singed fœtid odour is noticed on the person and clothes after each inspection of the apparatus, and when the mere running of the fingers through the hair, or the brushing or shaking of clothes, at once evolves sufficient dust to give rise to the peculiar characteristic odour; secondly, when the dust is heated on platinum foil over a lamp, when the organic matter is burned away with the same destructor odour; and thirdly, when some of the dust is added to water and the latter heated, when the steam evolved gives out a similar destructor smell.

Under the microscope and using powers of 70 to 140 diameters the destructor dust exhibits a marked lava-like or almost glassy structure of the fine particles, which is largely due to the disruptive action of the water thrown on the slaggy *débris* which had been withdrawn from the cells. The magnified particles are mainly jagged on the edges and are very adherent, whilst here and there minute balls or bombs and the moulds from which these have been blown are observed. The same structure is seen when the dust is fully burned on platinum or when heated with nitric acid so as to destroy the organic matters, which leaves a residue markedly silioeous and glassy in texture and composition.

All of these general characters are observed in the dusts taken from the discharging vaults of a working destructor where water is thrown on the red-hot *débris* taken from the cells, as also from the dust collected from the outside yards and grounds, as well as from the fences and walls, as well as stems and leaves of plants, examined in the neighbourhood, and even on the scum taken from a sheet of water situated 100 yards from the destructor.

The facility with which wind will carry destructor dust is even greater than in the case of ordinary road dust, for whilst the latter has a specific gravity of 2·434 (water = 1·000) the destructor gas has the specific gravity of 1·989, being a difference of 0·445 less density; and being therefore about 20 per cent. lighter than ordinary road dust, the destructor dust—equally fine in particles—is more readily lifted by winds and carried on in suspension. When deposited, however, as a layer on the leaves and stems of plants the destructor dust adheres more firmly to such owing to the jagged edges.

Ordinary road dust when diffused through the air by sifting through the fine sieve does not evolve any particular odour, and the same negative result is given when the road dust is treated with water. If placed on platinum and heated over a lamp the road dust merely evolves a slight corky straw odour, and has no singed fœtid smell. Under the microscope, the road dust is observed to consist of small stones, somewhat rounded and weathered, with only an occasional fragment of jagged glassy material.

Railway dust as taken from the permanent way and from passenger platforms, when diffused through the atmosphere yields no particular odour; when boiled in water it emits a slight sulphury smell; and when heated on platinum foil it evolves a burned coal odour, without any singed fœtid smell. Under the microscope, the fine particles are found to consist of minute cinders and minute stones—cinder and stone dust—with few fragments of jagged glassy material. The same characteristics are observed with other railway dust, such as those taken from the tops of railway tunnels, from the insides (not floors) of railway carriages, and from railway waiting-rooms.

The quantitative analyses of the various dusts also bring out the difference between destructor dust on the one hand and ordinary road dust and railway dust on the other.

The *destructor dust* taken from the drawing vaults outside yards, and grounds, yielded

12 to 15 per cent. of organic matter and
50 to 55 per cent. of siliceous matter,

and *destructor dust taken from the leaves of plants* (principally laurels) growing in the neighbourhood of a destructor gave

15 per cent. of organic matter and
55 to 58 per cent. of siliceous matter,

whilst ordinary *road dust* yielded

2½ to 5 per cent. of organic matter and
80 per cent. of siliceous matter,

and *railway dust* from the permanent way gave

10 per cent. of organic matter and
fully 70 per cent. of siliceous matter.

In regard to the soundness of the general practice of dealing with town refuse by fire, Authorities are unanimous. So long as ten years ago—a considerable period in connection with the evolution of the refuse destructor—Mr. T. Codrington, M. Inst. C.E. (Local Government Board), reported that "the burning of town refuse by furnaces *already in use* appears to be successfully carried out. There is no accumulation of an offensive material at the works, and very little smell. Everything combustible is burned within a few hours of collection without nuisance, and at a cost which compares favourably with the old system of carting the refuse to tips. A valuable means is at the same time provided for effectually disposing of infected bedding and clothing, condemned meat and provisions, and the carcases of diseased animals. Further improvements may be expected, but the results already attained show that the destruction of the refuse of towns by fire is not only practicable, but is the best, and often the only way of dealing with it in a manner to satisfy sanitary requirements."

Since the above was written much has been achieved in respect of the possible improvements there anticipated. The following points are among the essentials for a *good* destructor:—

(1) The cells and flues must be so arranged that the fumes are drawn over the fire so as to enter into combustion with the heat from the furnace whilst on their way to the main flue. The function of a specially constructed cremator is thus effected in the furnace or cell itself.

(2) The temperature of the cell must be sufficiently high to prevent the possibility of any undestroyed deleterious or offensive gases escaping from the chimney shaft. For this purpose a forced draught of either dry air or steam is necessary.

(3) The main flue should have a large sectional area so that the heat and fumes may travel slowly, and thus maintain greater heat in the chimney.

(4) Dust screens are ineffective for the purpose for which they are designed, and, in a properly designed destructor, are unnecessary.

(5) The cooling influence of a boiler should not be introduced to the heated gases until they have fully performed their functions in the cells, and are on their way to the chimney shaft.

(6) The surplus heat should be as great as possible for application to any of the numerous uses already indicated, consistent with the efficient performance by the destructor of its primary functions as a refuse burner.

Old iron, tins, &c., may be sorted and disposed of where possible in the old metal market. Or, if it can be done profitably, the tins may be heated in a special furnace (a type of which has already been referred to) in order to recover the best tin and solder for re-use.

Considering the nature of the work, a destructor should be worked in three eight-hours shifts. A bath-room in connection with the works will be found a great boon by the workmen.

No destructor undertaking can be expected to be thoroughly successful unless intelligently and carefully worked, so as to derive the full advantage of its points of good design and construction.

The efforts of the stokers should be towards obtaining a good, hard, vitreous clinker which shall command a sale, or be useful for road-making and other purposes.

In the course of the inquiries of the recent deputation of the

Cardiff Corporation, having inspected the refuse disposal of some fifteen districts, the experience gained led to the following general conclusions:—

(1) That destructor furnaces should be of the "high-temperature" type with forced draught.

(2) That, ton for ton consumed, the cost of destruction in high-temperature furnaces, including labour and repairs, is not greater, and possibly less, than in slow-combustion furnaces.

(3) That with the high-temperature furnace (1) no cremator is required; (2) these furnaces are more suitable for generating steam power of a high pressure.

(4) That of the furnaces with forced draught, that of Messrs. Beaman and Deas, as seen at Warrington and Dewsbury, is the most efficient.

(5) That one great drawback to the destructor system is the creation of such large percentages (from 30 to 40 per cent.) of ashes and clinker to be disposed of subsequent to the burning. In nearly every town visited the getting rid of this large residue was no trifling matter, and in some cases amounted to a real difficulty incurring considerable cost.

(6) That as a result of these difficulties, some districts have resorted to the manufacture of artificial paving slabs, but these being only of a *third-rate* quality they could not recommend this method of utilising the clinker in a stone-quarry district, such as Cardiff.

(7) That clinker should not be used in forming road bottomings, owing to the damage sustained by water and other pipes in contact with same from corrosion due to chemicals existing in the ashes, &c.

(8) That the process most suited to their own district would be a combination of the separating plant as used by the Chelsea Refuse Disposal Company, including various machinery for manufacturing paper, crushing bones, &c., with the destructor system, and recommend the erection of a refuse destructor of the Beaman and Deas type for consuming the dust, animal and vegetable matter, diseased meat, infected bedding and clothing, &c. This combination they expect to be able to work at a profit.

The deputation found that in nearly every place they visited the person in charge of the works considered his method of disposal of the refuse and his type of furnace the best and unsurpassable. The opinions expressed in regard to the different types of furnaces were so utterly at variance that the members of the deputation were left to form their own conclusions more from what they *saw* than from what they had *heard*. Where low-temperature destructors were in use the manager, they found, advocated that particular class of furnace, and deprecated the use of high-temperature furnaces, as being expensive in repairs and more costly in working, requiring more firing and clinkering, &c., while the advocates of high-temperature furnaces allege that the fierce heat and forced draught throw off particles of silica in a melting condition, which adhere to the brickwork and preserve it; and so great is the growth of this incrustation, that it has to be periodically knocked off.

CHAPTER VIII.

CHIMNEYS.

As the erection of a substantial chimney is an important item in connection with the building of a destructor installation, a few remarks on this part of the subject will doubtless be of interest.

A thoroughly good foundation is, of course, a first essential to the erection of such a structure. Sometimes, after the foundation has been laid in, it is allowed to remain untouched for a while in order that any possible settlement may take place before the shaft is proceeded with. The building should be proceeded with very slowly, so that the work may properly settle and avoid subsequent fracture. About 2ft. per day is the maximum progress that should be allowed. In the brickwork of the shaft, some engineers recommend three or four courses of stretchers to each course of headers. Copings should be well bound together with copper cramps or slate dowels, and should not have a large projection so as to catch the wind. The cross section of the coping should be such that its centre of gravity shall fall inside the outer line of the shaft.

The batter of the brickwork may be about 1 in 40 to 50; the diameter of the shaft at the base should be from one-tenth to one-twelfth of the height. As regards the thickness of brickwork, it is usual to make this 14in. thick from the top to a distance of 25ft. downwards, increasing in thickness by half a brick (4½in.) for each additional 25ft. downwards. The London County Council regulations require that the thickness of the walls shall increase 4½in. at every 20ft. from the top downwards; that the batter be 1 in 48; and that no cornice or other projection stand out more than the thickness of the brickwork at the top. The firebrick lining is, of course, to be additional to the thickness of the ordinary brickwork. These regulations to a great extent obviate the necessity of calculating the resistance to wind pressure.

The great chimney of the works of Messrs. Tennant and Co., St. Rollox, near Glasgow, which was erected from the designs of Messrs. Gordon and Hill, is, with the exception of the spire of Strasburg, the Great Pyramid, and the spire of St. Stephen's, at Vienna, the most lofty building in the world. The total height, from base of foundation to the top of the chimney, is 455½ft. The thickness of brickwork at the top is 14in., and at the ground level

2ft. 7½in. The external diameter at the top is 13ft. 6in., and at the ground level 40ft. The foundations extend to a depth of 20ft. below ground level.

Townsend's chimney, Glasgow, built 1857 to 1859, is also a very large one, and is 454ft. high from the ground surface to the cope. The outside diameter at ground surface is 32ft., at top of cope 12ft. 8in.; the sides have a straight batter, and the thickness varies from 7 bricks at base to 1½ at the top.

The following table[1] gives the proportions adopted in structures by the authorities named:—

Chimneys (R. M. and F. J. Bancroft).

Engineer.	Height above ground.	Depth of foundation.	Diameter at foundation.	Diameter, base of shaft.	Diameter at top of shaft.	Inside diameter at top.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Corbett, R.	454	14	50	32	12⅔	10⅓
Rankine	436	19	50	40½	13½	—
Johnson, I. J.	297	7	30	25	11	8⅔
Cubitt, J.	220	7	30	22	11	—
Bazalgette	158	21	—	17½	11¼	8
Livesey, G.	108	8	7⅓	7⅓	6½	5
Easton, E.	84½	18	16	11	6½	3
Hammer and Co.	70	10	14	7⅓	4	2½

Caps of cast iron are preferable to those of stone, and are more economical and reliable. If a stone cap is fixed it should be secured with gun-metal cramps, and not iron. Continuous gun-metal rings are sometimes used in stone caps of circular chimneys to bind the courses of stonework together. The fire-brick lining should not be bonded with the brickwork of the shaft, but must be free to expand or contract independently of the outside brickwork. The lining is laid in fire-clay, and headers are introduced into it at intervals—these project across the cavity at the back of the lining to the outer walls. Rows of hoop iron bond are sometimes adopted in the walls, but there is a risk of its expansion under high temperatures. The upper outlet of the cavity behind the lining should be oversailed with brickwork.

As regards *stability*, the only force tending to overturn a chimney or make it slide on any bed joint is the lateral pressure of the wind. This pressure, without sensible error in practice, is assumed to be horizontal, and of uniform intensity at all heights above the ground. Also, the surface exposed to the wind is treated as being vertical, ignoring the external batter given to tall chimneys; any slight error arising from this cause being on the side of safety.

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[1] Molesworth's "Engineering Formulæ."

The intensity of the pressure of the wind now usually allowed for in the design of structures of this character is 56 lb. per square foot, although a pressure of 80 lb. per square foot was registered at Bidston on the 27th December, 1868. The great St. Rollox chimney at Glasgow is capable of resisting 55 lb. per square foot at its weakest joint. An ample allowance should be provided for, as in high winds tall chimneys rock considerably, their caps often swinging through several feet, whilst the danger lies in the possibility of an exceptionally heavy gust happening to strike the shaft when in full swing to leeward.[1]

If the effect of wind pressure on a square chimney be taken as 1, it may safely be put at ·75 on a circular or octagonal structure. Molesworth gives: Square = 1, hexagon = ·75, octagon = ·65, circular = ·5.

In foreign climates, before designing a structure intended to resist lateral wind pressure, the greatest intensity of that pressure must be ascertained, either by observation of the effects of the wind on previous structures or by direct experiment.

"No calculations for sliding on the bed joints are required, since even in the smallest chimneys, only half a brick thick, for every foot of flat vertical surface exposed to the wind, more than a cubic foot of brickwork, weighing about 110 lb., would have to be moved. Now, taking the coefficient of friction for wet mortar as low as ·5, the resisting force would be more than 110 × ·5 = 55 lb.; therefore, even the smallest 4½in. brick chimney would safely resist a 55 lb. wind pressure, and a 9in. chimney nearly twice as much."[2]

Owing to the tendency of tall chimneys to rock in high winds, it is never safe to reckon upon either the tensile or adhesive strength of the mortar, and the stability of the structure should therefore be ensured without calling upon the mortar to exercise any tensile or cohesive strength whatever.

Wray gives the following rules for stability of chimneys:—

(1) The centre of pressure at the joint of minimum stability must remain within the limits which allow of the pressure varying from nil at the windward edge to a maximum at the leeward edge.

(2) The maximum intensity of pressure at the leeward edge of the

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[1] Wray's "Instruction in Construction."

[2] Wray's "Instruction in Construction."

joint of maximum compression must not exceed the safe limit of resistance of the materials under compression.

As regards the *limiting position of the centre of pressure*, Professor Rankine gives approximate positions for centres of pressure, under the condition that the pressure decreases uniformly from a maximum at one edge to nothing at the opposite edge. The distance of centre of pressure from edge of maximum compression for bed joints of square and circular shafts respectively are—

Hollow square (factory chimney), ⅓ diam. (or breadth of bed joint).
Circular ring „ „ ¼ diam. „ „

Thus, for example, in a square shaft, in order that there may not be any tendency for the joints to open, the centre of pressure must never approach nearer the edge of the bed joint of minimum stability than ⅓ D.

In considering the conditions of stability of any given bed joint, it may be noted that the area of a diametral vertical section of the part of the chimney above the given joint, multiplied by the greatest intensity of the pressure of the wind, gives the *total lateral wind pressure against the chimney.* If the chimney be circular, the effect may be taken as ·75 of the effect upon a flat surface as above mentioned.

The resultant of this total wind pressure may be assumed to act in a horizontal line through the centre of gravity of the vertical diametral section, and it acts with a leverage equal to the height of that centre above the given bed joint. The *moment of wind pressure* therefore is, the total wind pressure acting horizontally through the centre of gravity, multiplied by the height of that centre above the given bed joint; and to this moment the *least moment of stability* of the portion of the chimney above the joint should be equal. When the moment of wind pressure equals the moment of the weight of the shaft, the structure is on the brink of overturning.

The condition of stability of a chimney is therefore expressed by equating the moment of wind pressure about the joint of minimum stability with the moment of the weight of the shaft about the point at which the centre of pressure cuts the base.

To put this into the shape of a formula,

Let p = intensity of horizontal wind pressure in pounds per square foot.
H = height (in feet) of shaft above joint of minimum stability (or above given bed joint).
d = external diameter (in feet) at mean height above this joint.

h = height (feet) of centre of pressure of wind above same joint.

W = weight of portion of shaft above same joint.

m = leverage of W about centre of pressure when the latter has reached its limits.

$$m = \begin{cases} \text{For square chimneys} = (\frac{1}{2} - \frac{1}{6})\,D = \frac{1}{3}\,D \text{ from centre of shaft.} \\ \text{For circular chimneys} = (\frac{1}{2} - \frac{1}{4})\,D = \frac{1}{4}\,D \text{ from centre of shaft.} \end{cases}$$

D = external diameter of shaft at joint above mentioned.

Then, for square chimneys,

$$p \times \mathrm{H}d \times h = \mathrm{W} \times m.$$

And, for circular chimneys,

$$\cdot75 \times p \times \mathrm{H}d \times h = \mathrm{W} \times m.$$

If the calculated intensity of pressure (p) is within safe limits, and can only be attained under a wind force of 56 lb. per square foot, or more, acting at the same moment over the entire height of the shaft above the given bed joint, it will be evident that the stability of the structure is insured, without calling upon the mortar to exercise any tensile or cohesive strength whatever. An additional element of safety is also due to the vertical component of the wind striking on the slightly battered surface of the chimney, which for facility of calculation is treated as vertical.

If the wind pressure were to exceed that which the shaft was designed to withstand, the centre of pressure would approach somewhat nearer to the leeward side, the maximum intensity of the pressure would be increased, tension would be set up on the windward side, and probably the shaft eventually overturned.

As regards the manner in which chimneys are observed to give way to the pressure of the wind, Rankine says,[1] "This is generally observed to commence by the opening of one of the bed joints at the windward side of the chimney. A crack thus begins, which extends itself in a zig-zag form diagonally downwards along both sides of the chimney, tending to separate it into two parts, an upper leeward part and a lower windward part, divided from each other by a fissure extending obliquely downwards from windward to leeward. The final destruction of the chimney takes place, either by the horizontal shifting of the upper division until it loses its support from below, or by the crushing of a portion of the brickwork at the leeward side, from the too great concentration of pressure on it, or by both those causes combined; and in either case the upper portion of the structure falls in a shower of fragments, partly into the interior of the portion left standing, and partly on the ground beside its base."

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[1] "Manual of Civil Engineering" (C. Griffin and Co., London).

"It is obvious that in order that the stability of a chimney may be secure, no bed joint ought to tend to open at its leeward edge—that is to say, there ought to be some pressure at every point of each bed joint, except the extreme windward edge, where the intensity may diminish to nothing; and this condition is fulfilled with sufficient accuracy for practical purposes by assuming the pressure to be an uniformly varying pressure, and so limiting the position of the centre of pressure that the intensity of the leeward edge shall be double of the mean intensity."

Sharp bends in chimney flues check the draught, and for this reason they should be curved round to the new direction as easily as possible. The top of the horizontal main flue should be curved into the vertical flue of shaft, so as to increase the upward draught. When two flues from opposite directions enter the base of the shaft, a *mid-feather*, consisting of a vertical fire-brick dwarf wall, is built across the shaft to the top of the flue openings, in order to keep the two blasts from interfering with each other. This, however, is scarcely necessary if the flues are properly eased into the shaft as mentioned.

Chimneys are required (1) to carry off obnoxious gases; (2) to create a draught, and so facilitate combustion. The first requires adequate size, the second height. The weight of gas to be carried off by a chimney in a given time depends upon the size of chimney, the velocity of flow, and the density of the gas. But as the density decreases directly as the absolute temperature, while the velocity increases, with a given height, nearly as the square root of the temperature, it follows that there is a temperature at which the weight of gas delivered is a maximum. This is about 550 deg. above the surrounding air. Temperature, however, makes so little difference that at 550 deg. above, the quantity is only 4 per cent. greater than at 300 deg. Therefore height and area are the only elements necessary to consider in an ordinary chimney.

The intensity of draught is, however, independent of the size, and depends upon the difference in weight of the outside and inside columns of air, which varies nearly as the product of the height into the difference of temperature. This is usually stated in an equivalent column of water, and varies from 0 to 2in. The intensity of draught required varies with the kind and condition of the fuel, and the thickness of the fires. Wood requires the least, and fine coal and slack the most. To burn anthracite slack to advantage, a draught of $1\frac{1}{4}$in. of water is necessary, which can be attained by a well-proportioned chimney 175ft. high.

Molesworth gives the following rule for ascertaining the area of chimneys:—

Let a = area of fire-grate in square feet.
„ F = quantity of coal consumed per hour in lbs.
„ h = height of chimney in feet.
„ H.P. = horse-power of engine (indicated).
„ A = area of chimney at top in square inches.

Then—

$$A = \frac{15\,F}{\sqrt{h}} = \frac{100\,H\,P}{\sqrt{h}} = \frac{180\,a}{\sqrt{h}}\,.$$

$$h = \left(\frac{100\ \text{H.P.}}{A}\right)^2 = \left(\frac{180\,a}{A}\right)^2$$

The velocity of the draught may be calculated by the following formula:—

$$V = 1296\,\sqrt{h\,t}$$

where, V = velocity of draught in feet per hour.
h = vertical height of chimney in feet above fire-grate.
t = difference in temperature of heated column over external air in degrees Fah.

Wrought iron chimneys are sometimes erected in lieu of brick chimneys, especially if in the immediate vicinity of iron works. They are built of iron plates $\frac{1}{4}$in. to $\frac{3}{8}$in. thick, with $\frac{3}{8}$in. rivets, and are lined with fire-brick their whole height, and are bolted down to the base so as to require no stays. The Pennsylvania Steel Company at Sparrow's Point, Md., have an iron chimney 225ft. high above base line. Its diameter at 25ft. above base line is 17ft. (inside ironwork), and 13ft. 9in. inside the fire-brick lining. At the top it is 14ft. 8in. in diameter (inside ironwork). It is formed in five 40ft. lengths of iron plates of the following thicknesses, commencing at the top, viz., $\frac{1}{4}$in., $\frac{9}{32}$in., $\frac{5}{16}$in., $\frac{11}{32}$in., $\frac{3}{8}$in.

At Creusot there is an iron chimney 279ft. high. Iron chimneys require to be kept well painted to prevent rust, and generally, where not bolted down, they must be braced by rods or wires to surrounding objects.

CHAPTER IX.

BABCOCK AND WILCOX WATER-TUBE BOILER.

This type of boiler is now very extensively adopted in connection with Destructor installations, and a few remarks by way of description will therefore be given.

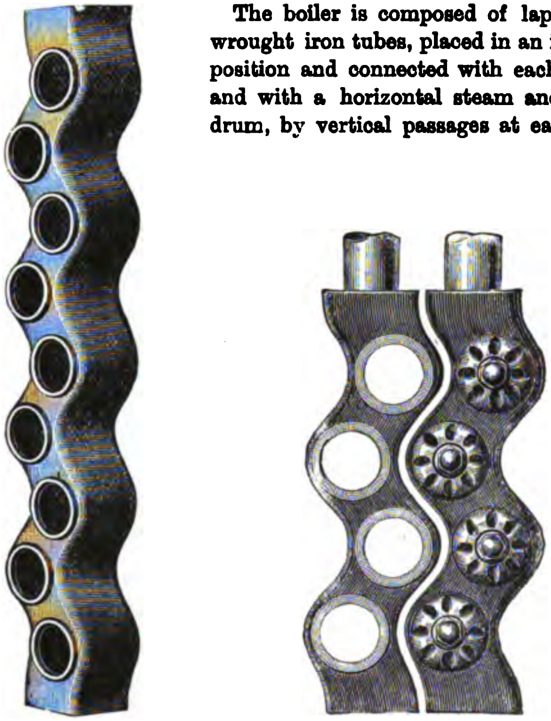

Fig. 35.—Staggered Header for Receiving Tubes.

The boiler is composed of lap-welded wrought iron tubes, placed in an inclined position and connected with each other, and with a horizontal steam and water drum, by vertical passages at each end, while a mud drum connects the tubes at the rear and lowest point in the boiler.

The end connections are in one piece for each vertical row of tubes, and are of such form (see Fig. 35) that the tubes are " staggered " (or so placed that each horizontal row comes over the spaces in the previous row). The holes are accurately sized, made tapering, and the tubes fixed therein by an expander. The sections thus formed are connected with the drum and with the mud drum also by short tubes expanded into bored holes, doing away with all bolts, and leaving a clear passage way between the several parts. The openings for cleaning opposite the end of each tube are closed by hand-hole plates, the joints of which are made in the most thorough manner by milling the surfaces to accurate metallic contact, and are held in place by wrought iron forged clamps and bolts. They are tested and made tight under a hydrostatic pressure of 300 lb. per square inch, iron to iron, and without rubber packing or other perishable substances.

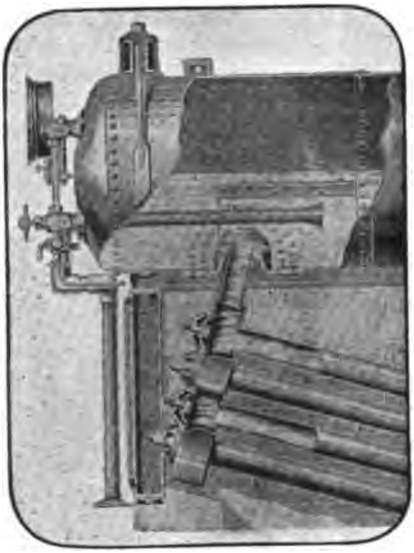

Fig. 36.—Detail of Water-tube Boiler—Partial Vertical Section.

The steam and water drums are made of flange iron or steel, of extra thickness, and double riveted. They can be made for any desired working pressure, but are always tested at 150 lb. per square inch unless otherwise ordered. The mud drums are of cast iron, as the best material to withstand corrosion, and are provided with ample means for cleaning.

In erecting this boiler, it is suspended entirely independent of the brickwork from wrought iron girders resting on iron columns. This avoids any straining of the boiler from unequal expansion between it and its enclosing walls, and permits the brickwork to be repaired

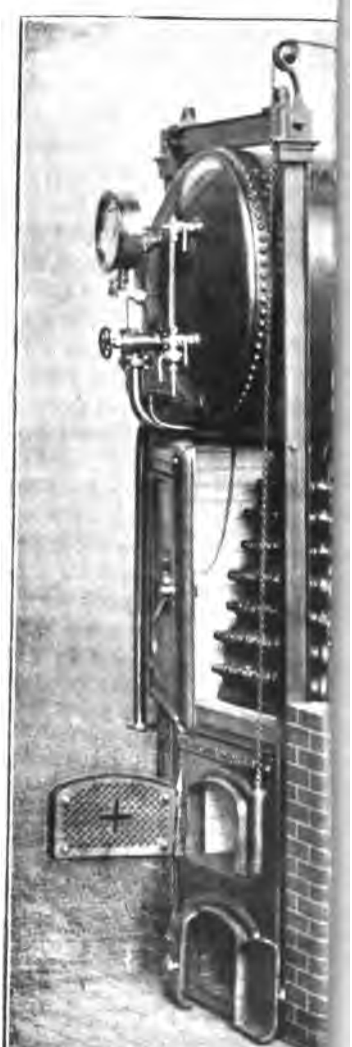

Fig. 57—B

[Face page 187

or removed if necessary without in any way disturbing the boiler. All the fixtures are extra heavy and of neat designs.

In operating this boiler in ordinary coal furnace work, the fire is made under the front and higher end of the tubes, and the products of combustion pass up between the tubes into a combustion chamber under the steam and water drum; from thence they pass down between the tubes, then once more up through the spaces between the tubes, and off to the chimney. The water inside the tubes, as it is heated, tends to rise towards the higher end, and as it is converted into steam—the mingled column of steam and water being of less specific gravity than the solid water at the back end of the boiler—rises through the vertical passages into the drum above the tubes, where the steam separates from the water, and the latter flows back to the rear and down again through the tubes in a continuous circulation. As the passages are all large and free, this circulation is very rapid, sweeping away the steam as fast as formed, and supplying its place with water, absorbing the heat of the fire to the best advantage, causing a thorough commingling of the water throughout the boiler and a consequent equal temperature, and preventing to a great degree the formation of deposits or incrustations upon the heating surfaces, sweeping them away and depositing them in the mud drum, whence they are blown out.

The steam is taken out at the top of the steam drum, near the back end of the boiler, after it has thoroughly separated from the water.

The following are amongst the advantages claimed for this type of boiler:—

(1) Thin heating surface in furnace.
(2) Joints removed from the fire.
(3) Large draught area and complete combustion.
(4) Thorough absorption of the heat and efficient circulation of water.
(5) Quick steaming and dryness of steam.
(6) Steadiness of water level.
(7) Freedom of expansion and safety from explosions.
(8) Cubical capacity, per horse-power, equal to that of the best practice in tubular boilers of the ordinary construction.
(9) Accessibility of cleaning and least loss of effect from dust on tubes.
(10) Durability, small cost of repairs, and ease of transportation.

Fig. 36 gives the detail of one end of the boiler, showing the connection of the tubes, &c., and Fig. 37 is a general view of the mode of setting.

CHAPTER X.

REFUSE DISPOSAL AND DESTRUCTOR INSTALLATIONS AT VARIOUS TOWNS.

Aberdeen.

The population of the district is 138,143, and the rateable value £686,004. The town refuse has hitherto been disposed of to the farmers in the neighbourhood for manure, but, in January, 1898, the Town Council resolved, in connection with a proposed extension of the electric lighting undertaking, to request Professor A. B. Kennedy, Consulting Electrical Engineer for the City, to consider the question of the erection of a Destructor for the utilisation of the city refuse.

Ashton-under-Lyne..

The area of the district is 1340 acres, the population 40,463, and the rateable value £156,778. The question of the disposal of the town refuse has recently been under consideration, and a sanitary sub-committee during the latter part of 1895 visited Oldham, Royton, Leeds, Bradford, Warrington, Toxteth Park, Dewsbury, and Liverpool, for the purpose of inspecting the working of various types of Refuse Destructors. The Destructors seen at the towns mentioned were—Horsfall's, Warner's, Fryer's, and Beaman and Deas'. The Corporation have decided to erect six cells of the Horsfall pattern. The waste heat will be utilised in connection with the Electric Lighting Plant. The Destructor Works are now in course of erection.

The refuse to be dealt with consists of wet midden and dry ashpit refuse.

Aston Manor.

Aston Manor has an area of about 943 acres, a population of about 70,000, and a rateable value of £172,000. About 70 tons of refuse are collected per day at a cost for collection (exclusive of interest on capital outlay) of 2s. per ton. The Refuse Destructor, which is situated in a populous district, consists of eight cells erected in 1892 by Messrs. Manlove, Alliott, and Co. at a cost of £6140. About 6 tons of refuse are destroyed per cell per day, at a cost for labour, materials, &c., of 7d. per ton. The furnaces are worked by two shifts of three men. A fume cremator burning breeze from ashes is in use, and the waste heat is utilised for mortar-making.

Barry.

The area of the district is 3800, the population 31,000, and the rateable value £172,500. The Urban District Council appointed a Committee in July, 1896, to inspect Refuse Destructors in various towns with a view to adopting this mode of disposal. Visits of inspection were made by the Committee to Bradford, Liverpool, Wallasey, Birkenhead, Warrington, Royton, Chelsea, Southampton, and Bristol. As a result of their visits the Committee learnt that the following are the necessary conditions for a perfect Destructor :—

(1) To destroy rapidly all unscreened refuse from a town of whatever description, without giving rise to any offence or possible nuisance.

(2) To reduce the refuse dealt with to the least possible amount of clinker.

(3) To deal with the refuse and the bye-products with the least possible expense and the greatest economy and efficiency.

(4) The temperature attained should be sufficiently high.

(5) The duration of exposure to a high temperature should be sufficiently long.

(6) All the vapours escaping from the refuse should be heated to a sufficient extent, and there should be no possibility of the escape of any undecomposed vapours into the chimney shaft.

Judging from the Destructors visited, they were of opinion that the one at Warrington erected by Messrs. Beaman and Deas is the nearest to fulfilling these requirements, and that the design might be improved upon by adopting Messrs. Boulnois and Brodie's patent charging apparatus.

The Committee, pursuant to instructions given in July, 1897, again visited certain towns with a view of seeing the latest in Refuse Destructors, and inspected the installations at Warrington, Liverpool, Dewsbury, Leyton, and Nottingham. In concluding their Report they state that—

> After seeing all the various Destructors, we are of opinion that Destructors of the type of Beaman and Deas should be erected, similar in every respect to those erected at Leyton, and we, therefore, beg to recommend that the matter be taken in hand at once , and that the Surveyor prepare Plans and Estimates of the same in conjunction with Messrs. Beaman and Deas. We recommend that the site be near the present depôt in Barry-road end.
>
> We also recommend that a separate estimate be prepared, showing the additional cost of providing Messrs. Boulnois and Brodie's patent charging apparatus in connection with the Beaman and Deas Destructor.

It is proposed to erect two cells of the Beaman and Deas' type. The refuse to be dealt with is ordinary house refuse and road scrapings. The two cells are guaranteed to destroy 30 tons per day of twenty-four hours. The actual quantity of refuse at present collected is about 20 tons per day. The surplus heat is to be applied to the generation

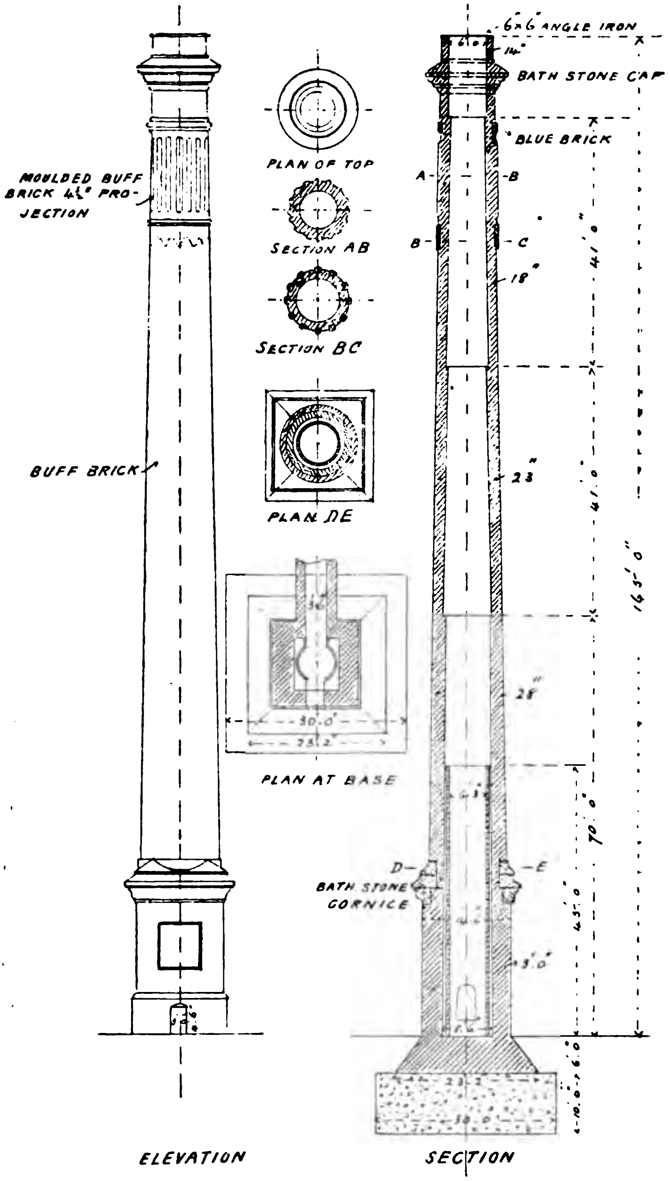

Fig. 38.—Bath Destructor, Chimney Shaft

of steam for driving a mortar mill, and probably a small electric light installation. It is intended in the future to apply the heat to generate electricity for lighting offices, abattoirs, &c., and probably for heating water for proposed Public Baths. Boilers are to be installed of 152-horse power. The shaft is to be 150ft. in height.

The estimated cost of the works is £6000.

Bath.

Bath has a population of 51,844, a rateable value of £302,824, and contains about 9000 inhabited houses. The area of the district is 3382 acres. About 30 tons of refuse per day are collected in summer and 60 tons in winter, at a cost of 3s. 3d. per ton for collection. No barging away is now done as formerly, and considerable saving is anticipated by the adoption of the Destructor system. The Destructor was erected by Messrs. Goddard, Massey, and Warner in 1895, and consists of eight cells (the "Perfectus" type). The chimney shaft and foundations formed a separate contract, and was executed by a local firm. The cost of the works was £7290, or, including site (1 acre), about £10,600. About 5 tons per cell per day are destroyed, but the amount varies according to the nature of the refuse. The clinker, which is about 30 per cent. of the bulk dealt with, is used for mortar and the manufacture of paving slabs, and is valued at 6d. per ton for rough and 1s. 6d. for ground. The best of the clinkers are picked out, crushed in the mill, and made into concrete paving slabs, the face of which, ½in. deep, is floated with ground china and granite chippings and cement. Some 5 or 6 tons of mortar are also made per day from the clinker and sold; also a few loads of screened ashes from the ashpits are disposed of at 2s. per ton, but the bulk of the residue from the burning is unsaleable, and is being tipped into a heap. There is a ready sale for the flue dust at 5s. per ton. The nearest house is 20 yards from the Destructor, and the complaints which have been received are said to be without foundation, although it is quite possible, in certain directions of the wind, that the characteristic Destructor smell may be detected in the nearest portions of the district standing at an elevation approximately on a level with the mouth of the shaft.

A multitubular boiler is fixed in the main flue, and steam is generated at 60 lb. per square inch pressure, and is utilised for driving an engine of 20-horse power, which works a mortar mill and clinker crusher. The boiler, which is 14ft. long by 8ft. diameter, is of the cylindrical multitubular type, and is said to be the largest in England of its class that is used for the purpose. There is, of course, a bye-pass flue which may be used when it is not required to heat the boiler. The cylinders of the engine are 10in. in diameter by 20in. stroke. The clinker mill is used for breaking up the furnace clinker, and is suitable for flattening old buckets and tins. It consists of there massive cast iron rollers, the top one having projections which break the clinker into pieces of a given size without crushing it to powder. There is a good chimney shaft 165ft. in height from the ground level, and is of circular section; the internal diameter of the lining is 6ft. 3in.; the external diameter of the base, 13ft.; and at the top, 7ft. 4in. The base is square, and has Bath stone cornices with blue brick facing round the bottom. The cap is formed of large segments of Bath stone. Special bricks formed to the proper radius are used for the outside face of the shaft. The inside has a lining to a height

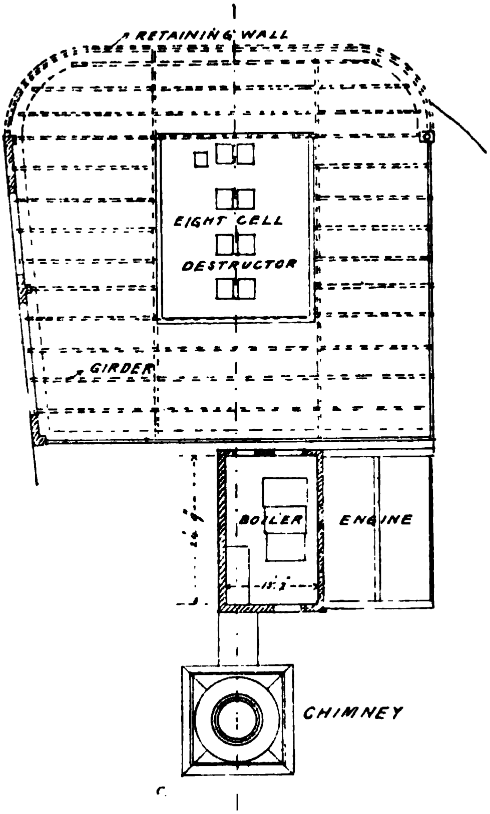

Fig. 39.—Bath Destructor, Ground Plan.

of 45ft. constructed of Stourbridge fire-bricks, behind which is an annular 6in. air space between it and the main brickwork. The whole structure stands upon a Portland cement concrete foundation 30ft. square by 18ft. thick.

Batley.

The area of the district is about 2039 acres, the population 30,000, and the rateable value £95,076. About 45 loads of refuse are collected per day at a cost of 1s. 9d. per load for collection. There is a 6-cell destructor, erected by Messrs. Manlove, Alliott, and Co. in 1887 and 1891, at a cost of about £1800. Only about 3·5 tons of refuse are destroyed per cell per day, the cost of destruction being 7½d. per ton. A fume cremator is in use, and coke is used as fuel, thus making the cost of cremating the fumes about 7d. per ton of refuse dealt with. The waste heat is used for lime grinding and pumping sewage. There is no night labour.

Battersea.

The area of the district is about 2169 acres, the population 165,115, the rateable value £883,831, and the inhabited houses number about 21,000. About 86½ tons of refuse are collected per day at a cost of about 4s. 1d. per ton for collection. The price for barging away is 2s. 6d. per ton. A 12-cell Destructor was erected in 1888 by Messrs. Manlove and Co. on an area of 1¾ acres. The cost of the works, exclusive of site, was about £12,000. The height of the shaft is 180ft. On the average 72 tons 8 cwt. of refuse are passed through the furnaces in 24 hours, *i.e.*, about 6 tons per cell; the cost is about 2s. 10½d. per ton. The residuum amounts to 33⅓ per cent. of the refuse burnt; part of the clinker is used for road-making and paving, part given away, and the fine ash is used for shingling. Fume cremators are provided, but, there being no nuisance from the shaft, they are not used. A 60-horse power multitubular boiler is also provided. The waste heat at the present time is only used to drive a portable engine working the clinker crusher for tar paving and silica paving. The utilisation of the surplus heat and the necessary modification of the furnaces has been under consideration. The Destructor is worked by eighteen men in three shifts of eight hours each. Since March, 1897, the Vestry has entered into contracts to barge a quantity of the house refuse as collected away from the parish wharf, the Vestry vans shooting the material into the barges, so that now the Destructor is not in full work. This has been found to be cheaper, owing to the favourable terms with the contractors.

The following particulars, prepared by Mr. J. T. Pilditch, Surveyor to the Vestry, may be taken as a model of how such accounts should be kept and presented. They give the details of the cost of the collection and disposal of dust and house refuse, and the several other works carried on at the Vestry's depôt in Culvert-road, from the 26th of March, 1896, to the 25th of March, 1897 :—

WORKING ACCOUNT.

	£	s.	d.	£	s.	d.	£	s.	d.
DESTRUCTORS.									
Paid for wages of manager (half cost)	109	2	4						
,, ,, clerk (half cost)	45	0	0						
,, ,, stokers and feeders	1,550	0	4						
,, ,, labourers, messengers, &c.	139	1	9	1,843	4	5			
,, fuel, oils, &c.				14	6	3			
,, oatmeal				14	18	0			
,, gas (proportion)				36	9	3			
,, water				10	1	9			
,, insurance				5	1	0			
,, rates and taxes (half charge)				89	14	7			
,, shoot for dust				785	19	11			
,, removal of old tins and fine ash				127	2	4			
,, repairs to buildings—									
Materials, &c.	4	19	7						
Wages	17	14	1	22	13	8			
,, new tools and repairs to tools—									
Materials, &c.	29	0	2						
Wages	63	14	1	92	14	3			
,, repairs to furnaces—									
Materials, &c.	11	11	4						
Wages	40	19	2	52	10	6			
				3,094	15	11			
Less Cash received for Clinker, &c.	24	3	1						
,, ,, weighing goods	3	0	8						
,, ,, old iron	22	0	0						
,, ,, old bottles	28	14	5	77	18	2			
Cost of establishment							3,016	17	9
COLLECTION.									
Paid for wages of manager (half cost)	109	2	5						
,, ,, clerk (half cost)	45	0	0						
,, ,, inspectors	82	16	8						
,, ,, drivers	1,825	3	4						
,, ,, fillers	1,416	0	0						
,, ,, shootmen and chain horse driver	169	0	2	3,647	2	7			
,, tools, baskets, and repairs to same—									
Materials	17	12	6						
Wages	18	3	1	35	15	7			
Carried forward				3,682	18	2	3,016	17	9

	£	s.	d.	£	s.	d.	£	s.	d.
Brought forward				3682	18	2	3,016	17	9
Paid for oils, sundries				5	14	0			
,, rates and taxes (half charge) ...				89	14	6			
,, harness repairs				38	1	7			
,, insurance (remitted)				—	—	—			
,, gas (proportion)				51	17	9			
,, water				25	16	3			
,, stable tools				4	4	8			
,, steam power (chaff cutting) ...				11	5	4			
,, stable sundries, oils, &c.				8	19	5			
,, veterinary fees for examination of and attendance upon horses ...				45	4	7			
,, provender				724	15	11			
,, shoeing—									
Materials	16	18	0						
Wages	89	19	9						
				106	17	9			
,, stable repairs—									
Materials	21	10	8						
Wages	30	7	5						
				51	18	1			
,, repairs to vans and ladders—									
Materials	65	8	3						
Wages	159	19	4						
				225	7	7			
,, wages of horsekeeper and stable helps				507	19	3			
,, fuel				4	8	6			
,, horse hire—									
Contractor	762	16	0						
Highway horses, 142 at 5s. 6d.	39	1	0						
				801	17	0			
,, Compensation, &c.				2	14	0			
				6,389	14	4			
Less—									
Cash received for removal and burning of trade refuse	245	2	0						
Cash received for sale of manure ...	5	10	0						
Dusting horses on silica paving work, 5 at 5s. 6d.	1	7	6						
Dusting horses on carting tar, 11 at 5s. 6d.	3	0	6						
Rent of disinfecting chamber	10	0	0						
				265	0	0			
Cost of collection							6,124	14	4
							9,141	12	1
Add for interest on first cost of horses and harness in stock	1,279	18	1 @ 5%	63	19	10			
Add depreciation on first cost of harness	261	19	6 @ 10%	26	3	11			
							90	3	9
Carried forward							9,231	15	10

	£	s.	d.		£.	s.	d.	£	s.	d.
Brought forward								9,231	15	10
Valuation of 20 horses in stock on March 25th, 1896...	857	0	0							
Add cost of 14 horses purchased during the year	794	0	0							
					1,651	0	0			
Valuation of 28 horses in stock on March 25th, 1897...	1,327	0	0							
Add cash received for 4 horses slaughtered and 2 sold	26	0	6							
					1,353	0	6			
Add depreciation on value of horses during the year								297	19	6
Add depreciation on first cost of plant, dust vans, carts, weighbridge, &c.	1,280	8	1	@ 10%	128	0	9			
Add depreciation on first cost of buildings	14,901	1	1	@ 1½%	223	10	0			
								351	10	9
Add annual proportion of capital (£12,000) borrowed for 20 years, and interest at 3½ per cent. ...					841	10	0			
Ditto on £2,500 borrowed for 15 years, and interest at 3½ per cent.					210	13	2			
Ditto on £775 borrowed for 15 years, and interest at 3 per cent.... ...					32	3	5			
								1,084	6	7
								£10,965	12	8

During the twelve months ending March 25th, 1897, 26,945 loads of house refuse have been collected, weighing 29,789 tons, including 1272 loads of trade refuse.

The average number of loads collected per day has been 88⅓, representing an average weight of 98 tons.

Included in the foregoing collection are 7243 loads of refuse, weighing 7967 tons 6 cwt., which have been disposed of other than by the destructor.

The average weight of refuse passed through the furnaces per day of twenty-four hours has been 72 tons 8 cwt.

The residue from the furnaces after the process of burning amounted to a total of 8574 tons 10 cwt. 3 qr., which was disposed of as follows:—

	Carted away by contractor.	Given away at the works.	Used by the Vestry.	Totals.
Clinker ...	2060 19 0 0 ...	1989 15 2 0 ...	1653 6 0 0 ...	5704 0 2 0
Fine ash...	276 7 3 0 ...	1659 0 0 0 ...	402 1 3 0 ...	2337 9 2 0
Flue dust	—— ...	105 7 0 0 ...	195 11 2 0 ...	300 18 2 0
Old tins ...	213 1 0 0 ...	—— ...	19 1 1 0 ...	232 2 1 0
	2550 7 3 0	3754 2 2 0	2270 0 2 0	8574 10 3 0

The total number of horses employed collecting during the twelve months, including a chain horse at the works, has been 8398½, as follows:—From dusting stud, 7194; from highway stud, 176; and hired from contractor, 1528½; giving an average of 28·89 horses per day.

The minimum number of horses employed collecting has been 16 per day, and the maximum number 44 per day; 482 days' work has been lost through ill and resting horses.

In 1885 there were 47½ miles of road repairable by the Vestry; at the present date there are 67¾ miles of roads in the parish, and the mileage is still being increased by the opening up of new estates.

MANUFACTURE OF TAR AND CONCRETE PAVING.

During the past twelve months a considerable portion of the residue from the furnaces, in the shape of clinker, &c., has been utilised as in former years in the manufacture of tar and concrete paving, a large quantity of which has been used in paving the footpaths of new streets and other paths in the parish, or sold to contractors and adjoining parishes. The profit to the dusting establishment, as shown in the following statements, amounts to £980 10s.

TAR PAVING ACCOUNT.

Expenditure.	£	s.	d.	*Receipts.*	£	s.	d.
Tools, plant, &c.	97	14	10	New streets...	309	5	7
Materials	923	14	10	Manufactured tar paving sold	183	7	7
Hired horses	125	17	4	Private works, gas and water trenches	618	11	10
Highway ditto	191	13	6	General repairs	3159	9	6
Dusting ditto	3	0	6	Improvements	166	19	6
Wages	2274	3	11				
Balance carried down ...	821	9	1				
	£4437	14	0		£4437	14	0

PROFIT AND LOSS ACCOUNT.

	£	s.	d.		£	s.	d.
10 per cent. on cost of plant (£241 5s. 3d.)	24	2	6	Balance brought down ...	821	9	1
10 per cent. on part cost of crusher (£111 10s. 3d.)	11	3	0	Value of stock on hand, March 25th, 1897 ...	293	17	6
Value of stock on hand, March 25th, 1896 ...	213	13	0				
Balance, net profit to credit of dusting establishment	866	8	1				
	£1115	6	7		£1115	6	7

SILICA PAVING ACCOUNT.

Expenditure.	£	s.	d.	*Receipts.*	£	s.	d.
Materials	121	11	9	Highway work, &c.	225	11	4
Tools	14	4	0	Private works	12	16	0
Rent, rates, &c....	40	6	10	Balance carried down ...	162	15	9
Oil, fuel, &c.	3	10	2				
Wages	219	13	4				
Horse hire	1	17	0				
	£401	3	1		£401	3	1

PROFIT AND LOSS ACCOUNT.

	£	s.	d.		£	s.	d.
10 per cent. on cost of plant (£115 14s. 5d.)	11	11	5	Value of stock on hand, March 25th, 1897 ...	695	2	0
10 per cent. on part cost of crusher (£37 3s. 5d.)	3	14	4				
Value of stock on hand, March 25th, 1896 ...	402	18	7				
Balance brought down ...	162	15	9				
Balance, net profit to credit of dusting establishment	114	1	11				
	£695	2	0		£695	2	0

The following shows the quantity and value of the manufactured goods in stock on March 25th, 1897 :—

	£	s.	d.	£	s.	d.
TAR PAVING.						
325 yards cube bottoming	113	15	0			
327½ yards cube topping	180	2	6			
				293	17	6
SILICA PAVING.						
4277⅜ yards super				695	2	0
Value of stock in hand				£988	19	6

	£	s.	d.	£	s.	d.
Cost of the dusting establishment for the twelve months ended March 25th, 1897, as per statement...				10,965	12	8
Deduct profit realised on the manufacture and sale of tar and silica paving, and value of tar and silica paving in stock on March 25th, 1897—						
Tar paving	866	8	1			
Silica paving	114	1	11			
				980	10	0
Net cost				£9,985	2	8

At the present time there are stabled at the dust depôt 28 horses, which are employed in the dusting work of the parish.

From the above it will be seen that during the year 29,789 tons of refuse were collected at a cost of 4s. 1·34d. per ton for collection, and that out of this quantity 21,822 tons were burnt in the Destructors at a cost of 2s. 10·3d. per ton, exclusive of repayment of principal and interest on capital outlay.

Bermondsey.

The area of the district is 627 acres, the population 85,475, and the rateable value £420,611. It is proposed to erect two pair of Beaman and Deas' cells in connection with an electric lighting scheme. The surplus steam is intended to be utilised in driving electric light machinery, mortar mills, and machinery at public baths. The refuse to be dealt with consists of ordinary house refuse and tanner's refuse, which it is anticipated will be consumed at the rate of about 16 tons per cell per day. It is intended to fix a 150-horse power boiler to each pair of cells.

Birkenhead.

The population in 1897 was 110,631, the rateable value £504,750, and the area of the district 3849 acres. There are two Destructor depôts, the installation first erected consists of a 12-cell Destructor, constructed in 1894, of the Manlove, Alliott, and Fryer's slow combustion type, but which has since been altered by drawing off the fumes from the front of the furnaces, after the style of the "Horsfall" Destructor, instead of at the back. To some of the furnaces forced air draught has been applied. These improvements have resulted in increasing the consumption of refuse and producing a better clinker.

There is a Jones' fume cremator, but it is only used when the wind is in the direction of the town. It is considered that it could be dispensed with if all the furnaces were altered to draw off the fumes from over the fire.

The consumption of refuse by the Destructor is at the rate of 7 tons per cell per day of 24 hours. Each load of refuse entering the depôt is weighed over a machine, and the exact results are accurately kept. The Borough Engineer does not recommend too great a forced draught, for fear of overheating and damaging the furnaces.

The clinkers resulting from the burning (about 33 per cent.) are partly made into mortar, the two mortar mills erected for the purpose making about 10 tons of mortar per day, the whole of which there is no difficulty in disposing of at 6s. 6d. per ton. All the mortar used by the Corporation workmen is obtained from the Destructor Works. As much of the remaining clinker and ashes as is required for concrete, road foundations, &c., by the Corporation is used for such purposes, and as much as persons will take is given away; generally 2d. per load is given the carter fetching it, to induce him to come again. The remainder is hauled away at a cost of 9d. per ton. Fine ashes obtained from under the furnace grates are used for bedding for paving purposes, and given away to those who will fetch it for garden footpaths, &c.

The steam for motive power, consisting of an engine for driving the mortar mills, the dynamo to light the depôt, and the fan for creating forced draught, is generated in a multitubular boiler from the heat of the Destructor furnaces.

The installation last erected consists of 12 cells by Messrs. Goddard, Massey, and Warner, with high temperature forced draught, mechanical rocking bars, &c. At this depôt other machinery may be fixed later.

The cost of disposal of the refuse is 10·21d. per ton after being delivered to the depôt.

If any accident occurs to the machinery the cells can easily be made to work by natural draught, without any partial choking of air inlets, &c.

The chimney stack is 180ft. in height, and the area of the land at the works is about 2 acres.

The works are carried on without any trace of nuisance.

Birmingham.

The area of the district is 12,705 acres; the population 501,241; the rateable value £2,254,888; and the number of inhabited houses about 104,500. About 700 loads of refuse, including ashes from pan closets, are collected daily. Boating away costs from 1s. 6d. to 1s. 9d. per ton. The Destructor Works were originally erected in 1877 by Messrs. Manlove and Co., and now consist of 47 cells, the chimney shafts being respectively 260ft., 150ft., and 150ft. in height. The Montague-street Works chimney (260ft.) has an internal diameter of 12ft. About 6 tons of refuse are destroyed per cell per day, leaving a residuum in clinker, &c., of 6 cwt. per ton destroyed. The cost of burning is 11d. per ton, for labour only. No cremator is used, and the Destructor is in the centre of a populous district, but no complaints have been made. As regards the question of waste heat, several tests have shown that 1 lb. of refuse will evaporate 1·79 lb. of water. The boilers are fixed directly over the furnaces. The water evaporated would develope (at Montague-street) over 500-indicated horse power. The greater part is used by the steam jacketed drying machine. There are twelve multitubular and two Galloway boilers at the Montague-street Wharf, and the surplus power is used for mortar making and for the manufacture of concentrated manure, &c., but not for electric lighting.

At the Montague-street Works (30 cells) there are twenty-seven stokers receiving from 26s. to 28s. per week, and twelve chargers at 22s. per week. They work in three eight-hour shifts. The cost of labour for destroying the refuse is 10·9d. per ton.

There is not a great demand for the clinker. It is used for concrete, road foundations, and part is sold at 1s. 6d. per 25 cwt.; the remainder is sent to shoot. When crushed and screened to 1½in. mesh it is sold at 1s. 6d. per load; ¼in. and ¾in. mesh at 2s. per ton.

The duties of collecting refuse and maintaining sewers were thrown upon the Corporation by the Birmingham Improvement Act of 1851. A proper sewerage system was then constructed and the collection of night-soil undertaken. The "pan" system prevails to a great extent in Birmingham. The pans are collected at night, once a week. Dry household refuse and other garbage is collected during the day, but the ashpits, a considerable number of which still exist, are emptied at night. The dry refuse is sifted and screened, being partly utilised as manure and partly burned in Manlove, Alliott, and Co.'s Destructors. The fæcal matter in the pans is converted into manure at Montague-street Wharf.

During the half year ending January, 1897, 17,228 tons of refuse were sent to "tips"; 48,845 tons were burned in the Destructors, and 89,800 tons of mixed manure and garbage were barged away or sent to fields by carts. Over 700 tons of poudrette or "pan" manure were manufactured. In collecting the pans and ashes, 122 men are employed at the refuse depôts and manure works, and in connection with the whole cleansing department.[1]

The interception, or "pan," system was introduced in 1874, and the 20,000 middens then existing, the total area of which was over 18 acres, were rapidly reduced in number. The pans in use are made of galvanised iron, are cylindrical in shape, and measure 18in. in diameter and 15in. in depth; they weigh 28 lb. each. They are placed immediately under the closet seat, and so arranged that they may be drawn out from the back. One pan is found sufficient for about nine persons for a week, and as Birmingham houses contain an average of 4·4 persons per house, there should be one closet to every two houses. These pans are, of course, intended for fæces and urine only. Household slops should not be emptied into them, and tubs are required for the dry household refuse.

It is obvious that the collection of these pans must be efficient and regular. They are collected between the hours of 10 p.m. and 8 a.m., and for which purpose the City is divided into districts. Every pan is collected once a week. The vans used carry 18 pans, and have a receptacle at the tail-end into which ash-tub refuse is tipped. The vans start with a load of clean pans, which are left in the privies from which the full ones are removed. When a pan is drawn out, it is covered with a tightly-fitting lid to prevent the slopping of the contents. Upon the arrival of a van at the wharf, the pans are emptied into tanks, and are then passed on to the pan washers, whose duty it is to see that each van is provided with a complement of clean pans. A van makes from three to five journeys a night, according to to the distance it has to travel. To reduce the cost of collection, stabling and depôts have been erected at suitable points in the city. All the depôts are adjacent to canals, and provide facilities for sending material away by boat. In collecting the pans and ashes from the same property, 61 horses and 122 men are employed. The men are provided with printed lists showing the calls they have to make on each journey.

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[1] The "Municipal Year Book" (Ed. Lloyd, Ltd.).

All the vans deliver their loads at the depôts in Montague-street, Shadwell-street, and Rotton Park-street. For the collection of *dry refuse* from shops and property provided with water-closets, thirty-three horses and and sixty-six men are employed, This work is done between the hours of 6 a.m. and 5.30 p.m. There are about 20,000 water-closets in the city. Covered wagons weighing about 28 cwt. are used. The average weight of the loads brought in during 1892 was 27 cwt.

In emptying *ashpits* forty horses and seventy-four men are employed, and the work is done between the hours of 10 p.m. and 8 a.m. The carts used measure 5ft. 10in. by 3ft. 10in. by 1ft. 11in. inside, and weigh 12½ cwt. A large proportion of the refuse collected from the old ashpits is useless as manure, about one-third only being used for that purpose. Part of the material is sent away by boats and part by rail, while a small amount is sent to fields by carts.

The *dry refuse* is riddled in octagonal rotating screens which separate the fine ash from the rougher material; the latter is further sorted by removing the broken crockery, brick-bats, tin cans, &c. On sanitary grounds, no attempt is made to collect rags from the refuse, which are burnt in the furnaces with other combustible material.[1]

Part of the fine ash is mixed in a pug-mill with the pan contents, and sold as manure. It is discharged into boats from the mixing machines. This mixed manure meets with considerable favour amongst farmers, but during recent years they have been directing their attention more especially to manure offered in a concentrated form. One great reason for this is, that by the use of concentrated manure the cost of labour and cartage—a considerable item in the expenses of a farm—is materially reduced.

The combustible material in the refuse is burnt in specially-designed furnaces. Altogether there are forty-seven furnaces in operation at the various wharves. The heat produced by the combustion of refuse is utilised for the generation of steam to evaporate the moisture from the excreta, which is made into concentrated manure. It also furnishes power required for the machinery at the wharves. The burning of the refuse reduces it to 30 per cent. of its original weight.

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[1] Pamphlet on "The Birmingham System of Refuse Disposal."

The clinker produced is useful for a variety of purposes. A considerable quantity is used by builders either as concrete or for mortar-making. It is also extensively used in the making of new roads. That which is not otherwise disposed of is taken to tips. Being entirely free from offensive matter, there is no danger in, or objection to, this course.

To increase the rate of combustion forced draught has been applied to most of the furnaces. During the year 1892 the quantity of refuse burned in each furnace averaged 36¼ tons per week of 132 hours. The average grate surface of the furnaces is about 36 square feet.

At the Montague-street Wharf part of the pan contents are mixed with fine ash and sold as manure, the rest of the material being manufactured into a highly concentrated manure by evaporation. The pan contents on arrival at the wharf are emptied into tanks, where they are mixed with sulphuric acid in order to fix the ammonia and prevent its evaporation under the action of heat. The excreta is next run into tanks immediately over the drying machines, which latter may be also charged direct from the receiving tanks. The storage tanks are fitted with a series of pipes through which the vapours from the drying machines pass on their way to the condenser. The exhaust steam from the engines is also utilised in a similar manner, so that the contents of the tanks are heated to about 212 deg. before being run into the machines. There are four steam drying machines. In section these machines resemble two cylinders joined together, leaving about three-fourths of the whole circle in each cylinder. They are 8ft. in diameter and 13ft. long, and are steam jacketed. Each cylinder is provided with a hollow shaft through its centre. These are heated by steam to assist the process of drying the material, and fitted with arms which are made to revolve in opposite directions, one set of arms meeting and passing through another set. The contents of the machine are thus constantly being broken up and kept from forming into lumps, The ends of the arms are fitted with scrapers which clear the surfaces of the plates, and thus prevent the heating surfaces from becoming ineffective.

A pair of diagonal steam engines, with cylinder 12in. in diameter and 18in. stroke, is used for giving the motion to the scraper shafts of each machine.

The vapour from the machines is drawn off by a pipe which conducts it through the storage tanks to a large Liebig's condenser. The water condensed passes into the sewer in a nearly inodorous condition, and the gas is passed over the fires of the furnaces, which destroy any organic matter that might otherwise have escaped into the chimney. The material in the evaporating machine is dried until it is of the consistency of a clod. If required, it is afterwards ground in a mill.

The working charge of these machines is 16 tons, and when dried to the proper consistency the weight of the manure discharged is about 25 cwt.

The quantity of the concentrated or poudrette manure produced in the year 1892 was about 800 tons.

The manure is packed in bags containing 1¼ cwt. each, and is chiefly sent away by rail. It sells at £6 per ton.

The following table shows the total quantity of refuse collected during the year 1897, and the methods of its disposal.

		Tons.
Refuse sent to tips, chiefly by boat		34,793
Refuse sent to tips by carts[1]		—
Refuse burnt in furnaces		96,309
Mixed manure, ashpit manure, fish, sweepings, sent to tips by boat, to fields by cart, or sent away by rail to order		74,855
Brick-bats sent to tips		416
Materials sold, comprising—		
Oyster shells	15	
Glass	19	
Scrap tin	296	
		330
Total		206,703

The total number of horses employed by the Health Committee, December 31st, 1892, was 180. The Committee also own thirty-four canal boats, which are in constant use.

Blackburn.

The area of the district is 6974 acres; the population about 130,000; and the rateable value about £451,325. About 130 loads of refuse are collected per day, and disposed of in an eight-cell destructor, erected in 1879 and 1890 by Messrs. Manlove and Co., the cost being about £8500. Six tons of refuse are dealt with per cell per day, leaving a residuum of about 30 per cent. A fume cremator is in regular use, in which coke is burnt; the cost of cremating the fumes is about 2¼d. per ton of refuse destroyed, and the cost of destroying the refuse is 10d. per ton. The eight cells and cremator developes 45-indicated horse power, which is used for driving mortar machinery.

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[1] In 1892, 6365 tons were disposed of in this manner.

Blackpool.

The area of the district is 3496 acres, the population varies very widely, according to the season, from about 40,000 up to 100,000, the rateable value is £290,382. About forty loads of refuse are collected per day at a cost for collection of 3s. per load. Barging away is done for 6d. per ton. The Destructor, as first installed, consists of eight cells, erected in 1890 by Messrs. Manlove and Co. at a cost of about £5129. The whole of the refuse is destroyed in the Destructor, leaving about 20 per cent. of clinker. The expenses of the Destructor for 1897 were £2140. A fume cremator is in regular use in which coke is used as fuel. Complaints of nuisance have been made, but are said not to have been well founded. The surplus heat is used for driving a fan to pump air for sewer ventilation.

Four additional cells, but of the Horsfall type, were erected in 1895. The amount of refuse burnt is estimated to be at the rate of 8½ tons per cell per twenty-four hours. The refuse is ordinary house refuse, with a slight admixture of garbage from fish shops, markets, and privies. The cost of burning per ton is 1s. 6½d., including all expenses except carting and interest and sinking fund on buildings. The surplus steam, which is derived from a 20-horse power boiler, supplies the power for forced draught and pumping water. It is also proposed to generate electricity for lighting the Destructor Works. The height of the shaft is 116ft.

The total cost of the Blackpool Destructors was £6272 5s. 7d.

Bolton.

The area of the district is 2361 acres, the population 121,433, and the rateable value £470,918. About 215 tons of refuse are collected daily at a cost of 3s. 1d. per ton for collection. It is disposed of partly by burning, partly by tipping to shoot, and a part is sold. The class of refuse dealt with in the Destructors consists of ordinary house refuse, sweepings from lock-up shops, and anything combustible which the neighbouring farmers will not take. There are two Destructor installations—one consisting of eight cells, erected in 1881 by Messrs. Manlove and Co. at a cost, including cells, ironwork, royalty, and chimney, of £4300. At this Destructor there is one Lancashire and one multitubular boiler, fire-tubed. The other installation, recently erected, consists of ten cells, principally of the Corporation's own design, with one Lancashire and two multitubular boilers, water-tubed. The cost of these works has not yet been finally ascertained.

During 1897, 33,963¾ tons of refuse were destroyed, but the

Destructors were not kept in full work. The cost of labour for burning was 8¾d. per ton, but after deducting the amount received on mortar sales the cost is reduced to about 2½d. per ton.

The waste heat generates steam for driving three engines, ten grinding mills for manure and mortar, one hoist for lifting clinkers from fire hole, and one capstan for hauling railway wagons; all is done out of the scavenging collection. The Destructors are not connected with any electric light undertaking. The two Lancashire boilers are 30ft. by 7ft. each, and about 70-horse power. The patent multitubular boiler was tested to 200 lb. per square inch, and works at a pressure of 120 lb.

The chimney shafts are 180ft. and 195ft. high respectively.

Bootle.

The area of the district is 1590 acres, the population 52,000, and the rateable value £456,033. The house refuse is destroyed in a 12-cell Destructor of the Leeds type. The furnaces are not worked to their full capacity during the twenty-four hours, owing to the method of collection of the refuse. The average cost for labour and materials of burning the refuse during 1897 was 10·6d. Boilers of 40-horse power are installed for use with the heat from the Destructor cells, and the surplus steam is utilised in driving concrete flag machinery and a mortar mill. The Destructor is not connected with any electric lighting scheme.

The chimney shaft is 170ft. in height. The total cost of the works, exclusive of site, was £9200.

Bournemouth.

The area of the district is 2593 acres, the population 54,798, and the rateable value £368,165. About 45 tons of refuse are collected daily, of which from 24 to 30 tons are burnt; that from the outlying districts is tipped. The Destructor was erected in 1887, and enlarged in 1891 and 1895 after the designs of Messrs. Fryer and Warner. The cost of the works was £3171. The Warner cells were built in 1891 and 1895. There are six cells, each of which deals with from 4 to 5 tons of refuse per day, leaving a residuum of 25 per cent., which is used for road-making. There is no sale for this residue. The cost of burning is 9d. per ton (labour and repairs only). No cremator is in use, and there are houses in the immediate vicinity of the site, but no complaints have been received. The chimney shaft is 140ft. in height, and the Destructor stands in two acres of ground. No use is at present made of the surplus heat.

Bradford.

The area of the district is 10,776 acres, the population 235,000, the rateable value £1,130,375, and the inhabited houses number about 48,500, the majority of which have ashpits in their yards, or court spaces, into which ashes and other materials are deposited by the occupiers. There are altogether about 30,000 ashpits and privies from which night-soil is collected about four times in twelve months by the Night-soil Contractor, at a cost of about £8430 per year. He employs 120 men and forty-five horses and carts. Seventy-four thousand tons or loads are collected annually at a cost of 2s. 3¼d. per ton. The excreta from the privies connected with the ashpits is mixed with the small ashes, and taken by the railway companies into the farming districts to be used by the farmers; it amounts to 14,650 tons annually. The remaining portion of the refuse is carted an average distance of one mile to one of the Destructor depôts to be burned. The Destructors were erected in 1880-1 and enlarged in 1882, 1886, and 1889 from designs of Messrs. Manlove and Co. There are 35 cells in all, as follows:—

Hamerton-street Destructor, 12 cells, costing £10,250.
Sunbridge-road Destructor, 9 cells, costing £7956.
Cliffe-lane Destructor, 8 cells, costing £6390.
Southfield-lane Destructor, 6 cells, costing £3010.

The Destructor at Hamerton-street has been working thirteen years, that at Sunbridge-road and Cliffe-lane two years, and that at Southfield-lane eight years. With one exception they are all in fairly populous districts. The four chimneys are each 180ft. high and 6ft. 6in. in internal diameter. A cremator is used at the beginning of the week only to assist in getting up steam.

The whole of the 35 cells were fitted in 1891 with the Horsfall patent forced draught apparatus.

At the *Hamerton-street Depôt* there are 12 cells of the Horsfall type. The material to be dealt with is unscreened ashpit and midden refuse, which is consumed at the rate of 9·13 tons per cell per twenty-four hours at a cost, for labour and materials, of 6d. per ton. The surplus steam is utilised in:—

1. Lighting the works by electricity.
2. Working mortar mills.
3. Driving clinker-crushing and screening machinery.
4. Manufacturing manure out of fish refuse.
5. Disinfecting bedding, &c.

It is further proposed to drive the machinery in the mechanics' shop and the chopping machinery in the stables. Also, although at present the electric lighting is only for use within the depôt, there is a probability of its being extended for a small area outside.

There are two multitubular boilers, each 11ft. long and 8ft. diameter, and of 100-horse power, installed for use with the heat from the Destructor cells, but they are insufficient to utilise the whole of the heat from the 12 cells, as the temperature of the gases escaping to the chimney is over 1000 deg. Fah. Some of the clinker is sold at 8d. per load, and some made into mortar, concrete, &c. Lias mortar sells at 6s. 8d. per ton; common mortar 5s. per ton.

Through the courtesy of Mr. J. H. Cox, M. Inst. C.E., City Surveyor, I am able to give the undermentioned particulars of a recent test carried out at some of the Bradford furnaces. It should be distinctly understood that this test is a *true record of a complete week's work*, starting at midnight on Sunday with the fires as they had been left on the previous Saturday, and 20 lb. pressure of steam, and working through till 9 p.m. on the following Saturday, and leaving fires banked and boiler tubes cleaned ready to resume on the Sunday night following.

Tests of the "Horsfall" Destructor, Bradford Installation, October 18th to 23rd, 1897.

Number of cells	**6**
Type of cells	**Back to back**
Duration of test...	**141 hours**
Nature of fuel	**Unscreened midden and market refuse**
Number of men employed, including boiler attendant	**7**
Wages	**4s. 8d. per day**
Total quantity of refuse burned	**721,280 lb. = 322 tons**
Total quantity of refuse burned per cell per twenty-four hours	**20,462 lb. = 9·13 tons**
Total quantity of refuse burned per cell per hour	**852·6 lb.**
Total weight of water evaporated	**523,000 lb.**
Total weight of water evaporated per hour... ...	**3709 lb.**
Total weight of water evaporated per cell per hour	**618 lb.**
Water evaporated per lb. of refuse burnt	**·725 lb.**
Weight of clinker produced	**205,460 lb. = 91·72 tons**
Weight of fine ash produced	**13,401 lb. = 6 tons**
Total weight of residuals	**218,861 lb. = 97·723 tons**
Percentage of residuals	**30·3**
Steam pressure maintained (by recorder)	**60 lb.**
Temperature of feed-water	**50 deg. Fah.**
Temperature of gases in main flue...	**1800 deg. Fah.**
Temperature of gases at chimney bottom	**900 deg. Fah.**

Average air pressure (water gauge)	⅝in.
Total indicated horse-power per hour at 20 lb. ...	185·45
Total indicated horse-power per cell, continuously	30·91
Indicated horse-power hours per ton burnt... ...	81

At the same time a test was made to find the amount of steam used by the patent steam jets, with the following results :—

Duration of test...	6 hours
Total weight of water evaporated	14,000 lb.
„ „ per hour	2333·3 lb.
„ „ per cell	388·8 lb.

Summary of Weights of Refuse taken during Tests.

	Tons	cwt.	qr.
Left in pit to start with	14	0	0
328 loads of ashpit refuse	290	5	0
22 loads of market refuse	16	18	0
3 loads of trade refuse	0	15	2
122 tradesmen's carts, averaging 2 cwt. each	12	4	0
	334	2	2
Less quantity left in pit	12	2	2
	322	0	0

Average weight of one load of night-soil	17 cwt. 3 qr.
„ „ market refuse	15 cwt. 1 qr.

During the test the power generated was utilised in the following manner :—

101 tons 5 cwt. 2 qr. of mortar made, value £26 16s. 6½d., and sold.
27 „ 0 „ 0 „ of crushed clinker, value 18s., made and sold.
3 „ 14 „ 0 „ of fish guano manufactured.
6 „ 0 „ 0 „ of old tins, &c., sold.

General remarks.—The whole of the water evaporated was measured through a Kennedy water meter, fixed direct to the boiler.

One ton of coke was used during the first four hours to raise steam, after which the fire was allowed to die out.

Price of coke, 2s. 6d. per ton.

The Destructors are approached by inclined roads, which have gradients of about 1 in 20, and are worked continually from twelve o'clock Sunday night to twelve o'clock at noon the Saturday following (being closed Saturday afternoon and all day Sunday) by two relays of twelve men, one relay working twelve hours by day and the other twelve hours by night, alternate weeks, or sixty-six hours per week, with periods of rest between each process of clinkering. The wages are 28s. per week each man.

Each cell contains 25 superficial feet of grate area, and rocking bars are fitted to the cells in place of the original fire-bars; but it is found that the clinkers stick to them, and so are not approved.

The cost of fuel, &c., for use in the cremator is expensive, and it is therefore only used when it is necessary to get up heat to generate steam sufficient for forced draught.

There is some smell at the Hamerton-street and Sunbridge-road Destructors owing to the quantity of excreta mixed with ashes and deposited at the site ready for burning, but the men do not appear to be affected thereby.

The refuse from the markets and fish dealers' shops, amounting to 60 or 80 loads per week, is dealt with in another portion of the building. It is ground up into a pulp in a mortar mill and sold as manure to farmers. This portion of the building is let to a private individual, who pays a rent of £100 per annum for same, and the refuse is disposed of by him as fish manure.

For the year April 1st, 1892, to 31st March, 1893, the *net* cost of working the *Hamerton-street Destructor* was £828 4s. 3d.; the cost per load of refuse burned, *exclusive* of interest and sinking fund on capital account, was 9d.; the cost, *including* interest and sinking fund, was 1s. 3d.; and the cost for coke breeze for cremators per load burnt was 2⅝d.

For the same period these figures for the *Sunbridge-road Destructor* were :—

	£	s.	d.
Net working expenses	894	2	9
Cost per load burnt, exclusive of interest, &c.	0	1	5½
Cost per load, including interest, &c.	0	2	1¾
Cost of fuel for cremator per load of refuse burnt ...	0	0	3½

Brighton.

The area of the district is 2620 acres, the population 120,500, and the rateable value £772,784. The Destructor consists of 12 cells, erected by Messrs. Manlove, Alliott, and Co., with Boulnois and Brodie's patent charging apparatus. The furnaces were fired for the first time in May, 1896. The class of refuse dealt with is ordinary house refuse and trade refuse. It is consumed at the rate of 7 tons per cell per twenty-four hours, and the cost of burning (labour and materials only) is 1s. 7d. per ton. The surplus steam, which is derived from a 30-horse power boiler, is utilised for driving mortar mills and stone-breaking machinery. At the Hollingdean-road depôt, where the Destructor is situated, artificial paving slabs are manufactured for use upon the footpaths at Brighton. The Destructor has no connection with the electric lighting of the town. The chimney shaft is 225ft. in height. The cost of the works, exclusive of site, was £16,679.

Bristol.

The area of the district, including the recently annexed areas of Horfield, Stapleton, and St. George, is 11,417 acres, the population 318,042, rateable value £1,343,044.

The following particulars of the Destructor Works are contained in a paper given by Mr. T. H. Yabbicom, the City Engineer of Bristol, at a meeting of the Association of Municipal and County Engineers held in September, 1896:—The Destructor was built and fires lighted in November, 1892. The 16 cells or furnaces are of the ordinary Fryer type, constructed by Messrs. Manlove and Alliott, with automatic dampers and water reservoirs underneath the fire-bars. Steam blast has been applied to eight of the furnaces, resulting in higher temperature and more perfect combustion; but this is certainly obtained at the expense of the brick lining. The area assigned to the Destructor is 1 acre 0 rod 10 poles. The Ordnance Datum level of the site is 30 50, and the level of the highest inhabited part of the district within one mile is 212, or a difference of 181·50; the chimney shaft is 180ft. high. No complaints of fumes have been received from anyone, but two of dust as affecting certain manufactures have had to be considered.

The soil on which the Destructor was built was of a most unstable character, the original clay having been excavated for brick-making and the holes filled in with rubbish. It was ascertained by borings that a bed of gravel nearly level would be met at a depth of 30ft. below the original surface of ground, and it was decided to go down to this.

The chimney shaft is carried on a block of concrete 31ft. 6in. by 31ft. 6in. by 25ft. deep, the bottom 3ft., where there was water, being composed of six of ballast to one of Portland cement, and the remainder of five of ballast to one of ground blue lias lime, of which the immediate neighbourhood supplies an excellent sample. The foundations for the Destructor and cremator were formed in the following manner:—Rows of shaft holes 6ft. by 4ft. were sunk as far as the gravel, and filled to within 3ft. 6in. of the ground level with concrete of similar constituents as used for the support of the chimney stack. These concrete piers were connected by brick arches 14in. thick, and the spandrils being levelled up the crown, three parallel walls 5ft. 3in. wide were formed. The distances from wall to wall, 13ft. 6in. and 16ft. respectively, were bridged over by means of Lindsay's steel decking, the troughs being 14in. deep and filled with fine concrete. On the platform so formed the Destructor, cremator, boiler, and superstructures were built, and no settlement has taken place in any part. The approach road to the tipping platform is carried on a series of brick arches supported from the gravel on concrete piers.

Although the fires were lighted in November, 1892, the heat was applied very gently at first, and it was not until June, 1893, that the cells were worked to their full capacity, when it was found that by damping down on Sunday about 560 tons could be passed through in

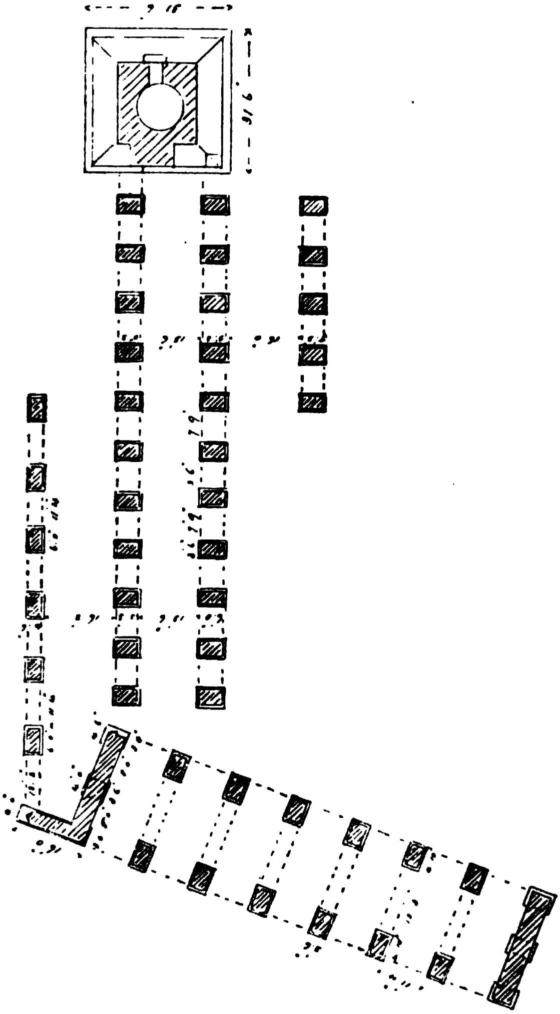

Fig. 40.—Plan of Foundation Concrete Piers.

the six working days, and that by working all seven days the amount specified in the contract with Messrs. Manlove and Alliott, namely, 640 tons, could be just reached; but the clinker was of a soft, inferior

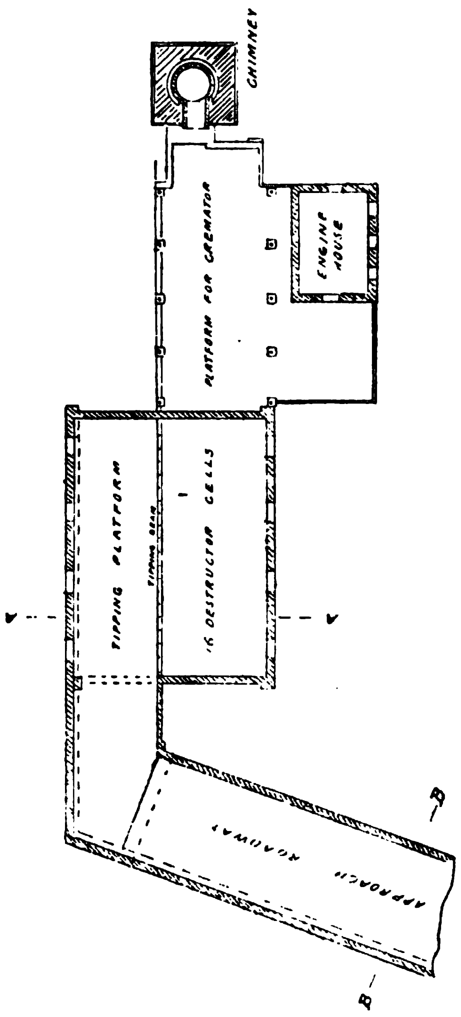

Fig. 41.—Plan at Ground Level showing General Arrangement.

character through the fires being drawn too rapidly. In the autumn of 1893 a steam blast was applied to eight cells on the south side, with the result that there was a considerable increase in the consumption of refuse, and a much higher temperature in the cells on that side, together with an improved clinker. For the past two years the

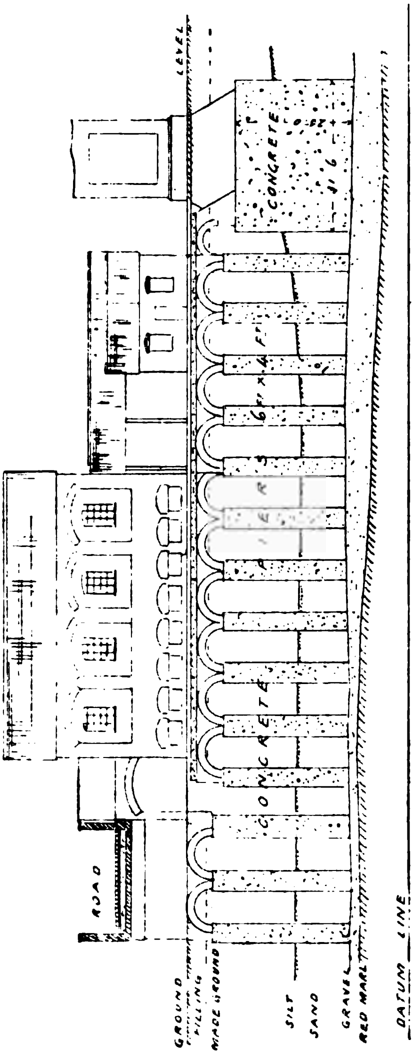

Fig. 42.—Longitudinal Section, showing Foundation Piers, &c.

average amount burnt, from twelve o'clock on Sunday night until noon on the following Saturday, has been 650 tons, which averages about 7½ tons per cell during twenty-four hours. The actual figures for the year ended March 31st, 1896, were 33,169 tons burnt, and during that period six holidays of one day each were allowed to the workmen. The firemen or stokers are eighteen in number, divided into three shifts of eight hours each, half-an-hour's rest and meal time being allowed during each shift, and, as already stated, no work is done on Saturday afternoon or Sunday; but it is doubtful whether it is good for the Destructor building to allow the periodic expansion and contraction to take place, which result from working at high pressure for six days and cooling down on the seventh, and whether the cracks and fissures generally found in Destructors after a few years' work are not due to this cause.

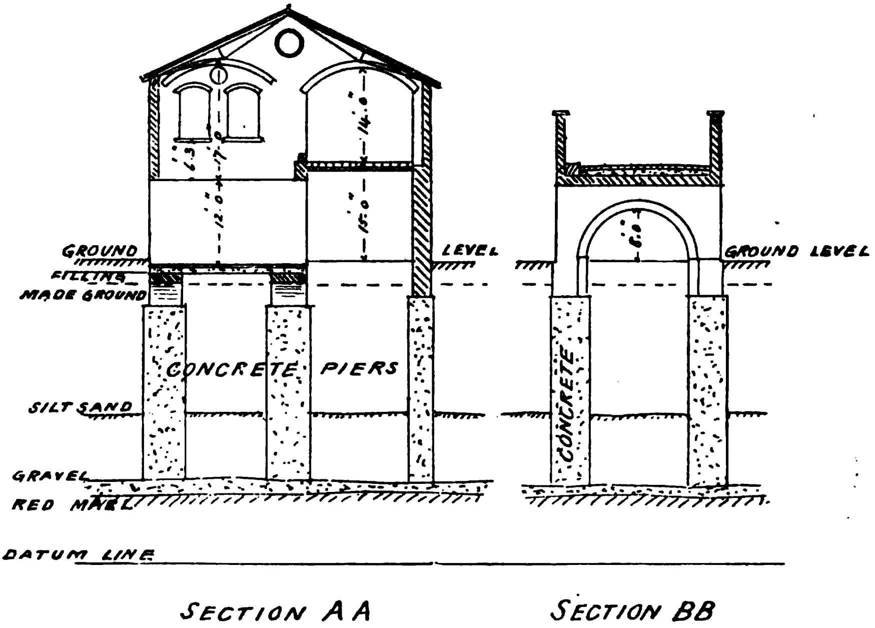

Fig. 43.—Cross Section: A A through Destructor Building, and B B through Approach Roadway.

The residuum after burning amounts, on the year's average, to a fraction over 34 per cent.; but varies considerably from day to day according as the refuse is drawn from the richer or poorer districts of the city—in fact, some from the East End comes in the form of almost unburnable dust.

Of the 11,500 tons of residue, 9667 were sold or put to some useful purpose, instead of being removed to a tip, which would have entailed a further cost of at least £725.

A vertical engine of 20-horse power, by Tangye, utilises the steam from the boiler, and drives two mortar pans and a stone-breaker. The Destructor is not worked in connection with any electric lighting scheme. The ground mortar is used on Corporation works, and any surplus made finds a ready sale. The rough clinker is an excellent ballast for new roads and footpaths; the finer is useful for tar paving, and with Portland cement forms good artificial stone, either in the form of flagging, steps, window-sills, door-heads, sink drips, pillar blocks, and a great variety of purposes. Recently the sides and bottom of one of the swimming baths belonging to the Corporation have been covered with a layer compounded of the residue, Portland cement, and chalk, forming a clean, bright, and impervious lining—easily cleansed.

During the twelve months ended March 31st, 1896, the following residues were used:—

	Tons.
Fine ashes	96
Breeze	540
Screened ashes	3491
Rough ashes	12
Clinkers	2734
Clinkers used in ground mortar	2736
Flue dust	58
Total	9667

The Destructor was erected upon land which belonged to the Corporation, situated in Albert-road, St. Philip's, Bristol, near the river Avon. The special arrangements to secure a firm *foundation* were expensive, costing £2909; the *Destructor*, *cremator*, *boiler*, *superstructures*, *approach road*, and *offices* cost £6820, and the *chimney shaft* £1689, making a total of £11,418 expended before commencing work. Since then £1442 have been spent on the *engine*, *mortar pans*, and *shedding*.

The outlay during the year ended March 31st, 1896, for wages of all persons directly or indirectly connected with the work, repairs, and all other charges, not including interest on first cost, amounted to £3600, and the credit by the sale of residual products to £1522, leaving a balance of expenses of £2078, about 1s. 8d. per ton on the amount of refuse burnt.

At the meeting above referred to, the City Engineer (Mr. Yabbicom) also said, "With regard to the use of forced blasts I am quite convinced as to the deterioration caused by excessive use of steam blast to the lining of the flues. At the present time we have been obliged to renew a considerable portion of the fire-clay lining in consequence of its being burnt out, although it has only been in use four years. Four years is a fair length of time, and the lining has had no repair until a month ago; but still I am convinced that excessive forced blasts are a mistake. It is better to leave the material in the furnace a longer time rather than force it and get very high temperatures, which injure not only the cells, but the main flue. We are paying 27s. a week to the firemen. One reason for the high percentage of residue —and I do not think in Bristol we shall have a chance of reducing it—is that much of the local coal is of a non-bituminous character, and the refuse coming from the lower part of the city is in the form of an unburnable ash. The figures are absolutely accurate. Every ton is weighed in and every ton is weighed out."

Figs. 40, 41, 42, and 43 illustrate the nature of the special foundations necessary owing to the unstable character of the ground.

Brussels.

Sanitary Conditions in 1887.—Brussels annually produces about 80,000 tons of household and street refuse, which is sold by boatloads to farmers, who use it as manure. When there is no demand it is stored in the "Refuse Farm" at Neder-Over-Heembeek. The storage at Neder-Over-Heembeek is fraught with heavy expenses. Until recently the Refuse Farm got rid of the material by using it for levelling uneven tracts of land outside the town. In future it will not be possible to do this, owing to the strong objections raised against this course by the Health Committees of neighbouring communities. The difficulty of disposing of the refuse has become more and more serious, for the quantity sold as manure has been steadily decreasing year by year, owing partly to the introduction of chemical manures, partly to the competition of the refuse from other towns, but chiefly to the depression in agriculture.

Without discussing the question, important though it be, of the cost of carrying on the Refuse Farm under these circumstances, it is evident that the *Administration Communale* will have to provide against the contingency of an epidemic breaking out in Brussels, when it would be impossible to sell the refuse, and all the material stored would have to be disinfected.

Report of Special Commission.—For the purpose of finding a solution to the difficulties referred to above, the Administration appointed a Committee of five to visit England and inspect the systems of refuse cremation in vogue in London, Birmingham, and Leeds. The Committee arrived at the following conclusions:—

(1) That cremation is the most hygienic treatment of refuse; and that well-constructed and carefully-regulated furnaces do not create a nuisance.

(2) That no definite judgment can be formed regarding the economic side of the question from the figures obtained in London, Birmingham, and Leeds. Local conditions enter largely into such calculations. One essential condition which all localities have in common, however, is that the Destructor must be installed near the town, in order to reduce the cost of transportation of refuse as far as possible. The best site for the Brussels Destructor would be in the neighbourhood of the "Refuse Farm" on the Voirie Quay. Supposing this site to be agreed upon, the following rough estimate, comparing the receipts and expenditure of the present system with the probable results of Destructor furnaces, may be accepted as fairly accurate:—The present cost of disposing of the refuse is estimated at 65,000f.; the receipts from the sale of manure, at 70,000f.; showing a profit of 5000f. If each cell consumes—as at Leeds—$6\frac{1}{2}$ tons in twenty-four hours, it would require thirty cells, which might be arranged in three blocks of ten, to consume 200 tons, the maximum daily amount of refuse collected in winter. The cost of this installation is shown, approximately, by the following table:—

	Francs.
Plot of land ($\frac{1}{2}$ to $\frac{3}{4}$ hectare)	140,000
30 cells at 2000 each	60,000
Shed, 1200 m. square	24,000
Chimneys of fireproof brick, 30 m. high	7,500
Working tunnels, paving, &c.	12,000
Miscellaneous...	50,000
Unforeseen expenses	6,500
	300,000

The Commission is of opinion that, except in times of epidemic, the refuse should continue to be sold, but should be carefully picked over, in order to increase its value as manure; leaving only the worthless material to be cremated. The whole of the refuse could be burnt when it would be found impossible to sell it. It is calculated that to consume this worthless refuse ten cells would have to be worked all the year round, ten more for two summer and three winter months, and the remaining ten for four winter months. The working expenses for a group of ten cells for twelve months are as follows:—

	Francs.
Salaries and wages	9,684
Repairs	2,000
Miscellaneous	1,000
Total	12,684

The cost of working the entire number of cells required would therefore be 22,197f. To this must be added the cost of carriage of refuse—5000f.—and the interest and amortisation of the capital of 300,000f. building cost, viz., 9810f.

This would bring the working expenses of the Destructor up to 37,007f. The expense of disposing of the picked refuse as manure would be as follows :—

	Francs.
Embarkation of refuse	7,000
Maintenance of boats	5,000
Navigation	15,000
Towage	4,500
Superintendence	2,400
	33,900

The total cost of the new system would therefore amount to 70,907f. It is assumed that the decrease in the quantity of refuse sold as manure would be counterbalanced by the increase in its quality, and that the same sum as at present would be realised from its sale, namely, 70,000f. Thus the receipts and expenditure of the new system would be even, while with the present system there is a profit of 5000f. In making this calculation, however, the Commission has not taken into consideration the sum that could be realised by the sale of that portion of the land at Neder-over-Heembeek, which would no longer be required, nor, in estimating the cost of the present system, the interest and amortisation of the capital this property represents.

The Commission advocates the adoption of the treatment of refuse by cremation, as practised in Leeds.

TRIAL REFUSE DESTRUCTOR.

As the result of the visit of the Special Commission to England in 1887, the Administration of Brussels in 1891 passed a vote authorising the construction of a trial furnace in the yard of the establishment on the Voirie Quay, at Molenbeek-Saint-Jean. The main object of this trial furnace was to show that the household refuse of towns can be cremated without the addition of any combustible, and that such installations do not create a nuisance in the neighbourhood. The trial installation comprises :—Two cells, placed back to back; one horizontal flue; one chimney. The cells are enclosed in brickwork, with a central *lanterneau*, forming a rectangular mass, measuring 10·22 m. by 4·44 m. and 4·20 m. high.

The refuse is brought to the top of the furnace by means of a small wagon placed on a platform over the charging hopper. There is only one hopper for the two cells. This part of the installation is only temporary. When the installation is completed—that is, when it will consist of a rank of cells capable of burning the whole of the town's refuse—the various charging reservoirs will be connected by a slightly inclined roadway upon which a tip-wagon will run.

The material is drawn down into the furnace from the charging hopper through an opening in the side of the cell. A trap-door above this opening provides for the introduction of bulky articles into the fire, and also enables the attendants to examine the state of the material upon the drying hearth. This drying hearth is an inclined cast iron plate upon which the refuse falls through the charging entrance. The hearth is heated from below by the hot gases from the fire. It is inclined in such a way that the refuse, when dried, glides of its own accord on to the fire-grate. A vertical partition regulates the depth of the layer of drying material. The feeding of the grate is thus performed automatically. The grate has an area of four square metres (43 square feet), with spaces eight millimetres (about three-tenths of an inch) wide. It is formed of bars one metre long, the back part being inclined at an angle of 35 deg., the front at an angle of 22 deg. from the drying hearth; this facilitates the charging of the grate. The hearth can be hermetically sealed during the process of cremation by hinged doors with balance weights. The air necessary to combustion is supplied to the grate from below by two fans.

The gases produced by the combustion of the refuse are carried off through an opening over the fire-bridge, thus they do not pass over the material on the drying hearth, and do not carry away with them any of the vapours arising from this partially dried refuse. The flue through which the gases pass runs over the bridge and discharges its contents at the head of the drying hearth. The gases disperse beneath the hearth, heating the entire surface, and are then carried off through a vertical flue into the main flue, through which they pass into the chimney. This chimney is 2 metres in diameter and 33 metres high.

To prevent the noxious gases from the chimney from dispersing in the air a "heat recuperator" has been introduced; the air which passes through it is discharged into the furnace below the exit of the gases. The air thus heated attains a temperature sufficiently high to burn all the carbonic oxide formed in the cell, and at the same time it raises the temperature of the gaseous current that passes up the chimney. This installation has cost 19,042·98 francs.

Experiments carried on with it have proved: — (1) That the refuse burns without the help of any additional combustible; (2) that the matter which has passed through the furnace is completely disinfected; (3) that the furnaces can be established in the neighbourhood of dwelling-houses without causing annoyance. The amount of refuse which can be destroyed varies considerably. It varies according as to whether the refuse has been picked over or sent to the furnaces just as it comes from the town; it also varies according to the season of the year. It has been calculated that, on an average, each cell consumes 15 tons of picked household refuse in twenty-four hours—that is to say, refuse that has been separated from the earth, dust, fine ash, &c., which it contains.

Exact Results of Two Experiments.

(A) From October 7th to 13th, 1895. Sifted refuse, two cells.

Duration of experiment, 69 hours (the furnaces were not re-charged during the night).

Number of cubic metres of refuse consumed, 201·192 cubic metres; total weight, 93,820 kilos., *i.e.*, 466 kilos. per cubic metre.

Consumption per hour, 1360 kilos.

Residues: 28,970 kilos., or 42·402 cubic metres, of clinker; 11,630 kilos., or 12·804 cubic metres, of fine ashes. That is, 43 per cent. in weight and 27 per cent. in bulk of the total quantity of material consumed.

In considering the weight of the residue, it should be remembered that the clinker on being taken from the furnace is liberally watered, and that the fine ashes fall into a water pit and are removed in a damp state.

(B) From October 15th to 21st, 1895. Unsifted refuse, two cells.

Duration of experiment, 70 hours.

Number of cubic metres of refuse consumed, 149·698 cubic metres; total weight, 77,215 kilos., *i.e.*, 516 kilos. per cubic metre.

Consumption per hour, 1103 kilos.

Residues, 44,660 kilos., or 56·805 cubic metres of clinker and fine ashes. That is, 57 per cent. in weight and 38 per cent. in bulk of the total quantity of material consumed.

In this case also the damp condition of the residues must be taken into consideration.

Analysis of Gas taken from Large Horizontal Flue.

Six analyses made by the Chemist of the Administration give the following average:—

Carbonic acid	0·6
Oxygen	6·4
Carbonic oxide	1·6
Water vapour	1·5
Ammonia	Nil
Sulphuretted hydrogen	Nil

Four analyses made in the presence of M. Bruylants, Professor of Chemistry at the University of Louvain, Member of the Higher Council of Hygiene, and controlled by other re-agents than those employed by the town's chemist:—

	1.	2.	3.	4.
Carbonic acid	0·8	0·8	1·2	1·1
Oxygen	4·8	4·6	4·6	4·5
Carbonic oxide	1·2	1·0	1·6	1·3
Ammonia	Nil			

Analysis of Clinker.

Loss in calcination (combined water, organic matter, CO^2, &c.)	3·66
Silica	53·25
Oxide of iron and aluminium	28·38
Lime	8·23
Magnesia	1·06
Potash	1·24
Soda	2·18
Phosphoric acid (total)	1·37
„ soluble 0·87	—
Sulphuric acid	0·31
Various	0·32
	100·00

The potash is worth ... ... 0·40f. per kilogramme
The phosphoric acid... ... ... 0·15f. „

Analysis of the Fine Earth obtained by Sifting the Refuse.

1000 kilos. contain—	Damp.	Dry.
Water	181·00	—
Loss by fire (organic matter, water, and combin. CO^2, &c.)	233·74	285·40
Insolubles (sand, silica, &c.)	463·88	566·39
Oxide of iron and aluminium	66·61	81·33
Lime	24·00	29·29
Magnesia	2·23	2·72
Potash	3·96	4·83
Soda	10·88	13·28
Phosphoric acid (total)	4·67	5·70
Various (sulphuric acid, chlorine, &c.)	9·03	11·06
	1000·00	1000·00
Azote from organic matter	4·78 p.m.	5·83 p.m.

Analysis of the Fine Ash (taken from the ashpit).

	Damp.	Dry.
Water	264·70	—
Organic matter	120·38	163·70
Lime	37·49	50·99
Magnesia	1·74	2·37
Potash	5·65	7·69
Soda	10·86	13·74
Oxide of iron	37·73	51·32
Aluminium	32·87	45·70
Phosphoric acid	3·25	4·42
Sulphuric acid	9·24	12·57
Carbonic acid	9·55	13·00
Chlorine	0·65	0·89
Insoluble matter	465·89	633·61
	1000·00	1000·00

Up to the present the Refuse Destructor installation has not been completed. This delay is caused by the new disposition of the streets which has been decreed with a view to the future maritime installations of Brussels, and which makes it impossible for the furnaces to be erected upon the spot originally selected. As no other site can be assigned to the Destructor, the plans of the Administration have been postponed.

A complete change in the arrangements and working of the Refuse Farm is, however, quite unavoidable and cannot be long deferred, although it is impossible to find a solution of the difficulty until the approaches, &c., to the new river basins have been definitely determined.

Burnley.

The area of the district is 4015 acres, the population 102,805, and the rateable value £339,000. The old-fashioned "Beehive" Destructor has been in regular use for many years at Burnley for the purpose of destroying offal, garbage, diseased meat, street sweepings, market refuse, and occasionally, when required, the ashpit contents of the yard. The consumption of average refuse, *i.e.*, taking combustible and non-combustible together, has been at the rate of 15 cwt. per hour. The furnace has an internal diameter of 7ft. and a 9in. fire-brick lining. Needless to say, this type of Destructor is now quite out of date, and its working will very shortly be discontinued.

The Burnley Corporation are at present putting down a Beaman and Deas Destructor at their new Health Depôt, and this will shortly be in working order. Two cells of this type are being first erected, but, if satisfactory, the number will probably be increased to eight. The class of refuse to be dealt with is market garbage and slaughter-house refuse mixed with ashes, which it is anticipated will be consumed at the rate of not less than 15 tons per cell per day. The surplus steam is to be used for driving mortar mills, for working a disinfector, and for supplying the electric lighting station adjoining. The height of the chimney shaft is 240ft. The cost of the whole scheme is £18,000, but only £12,000 is being spent at present. This includes the Destructor and building, preparing yard and paving same, office block and dwellings, disinfector buildings, wash-house, &c., and cart shed.

Burslem.

The area of the district is about 2585 acres, the population 34,880, and the rateable value £136,983. About 30 tons of refuse are collected daily, at a cost for collection of 1s. 1d. The Destructor was erected in 1889 by Messrs. Manlove, Alliott, and Co., and occupies a site two acres in area. The Destructor consists of four cells, costing (exclusive of site and chimney) £2410. About 6 tons of refuse are dealt with per cell per day, leaving a residue of 30 per cent. The class of refuse to be dealt with consists of ordinary house refuse, and, in the summer, night-soil mixed with ashes. The highest inhabited part of the district, within a mile radius of the Destructor, is 143ft. above the level of the site of the works; the height of the shaft is only 80ft., but no complaints have been received. A " fume cremator " is in regular use, which is fed with screened ashes, and the waste heat (from cremator only) is utilised for raising steam in a small boiler for driving a fan for forced blast to cells. The cost of labour and materials in burning the refuse is 1s. 5d. per ton.

Burton-on-Trent.

The area of the district is 4025 acres, the population 50,000, and the rateable value £265,828. An eight-cell Destructor was erected in 1890 upon a site three roods in area, from the designs of Messrs. Manlove and Co. (Fryer's patent), at a cost of £4266, which sum included £534 for a Washington Lyon's Disinfector and mortar mills. The surplus heat is used for generating steam in a 12-horse power boiler for driving the mortar mills, and until recently for supplying steam to the disinfector, which has now been removed to the new hospital. The steam is also used for chopping hay, steaming chop, corn-grinding, and driving a mortar mill. A fume cremator is in use in which breeze and waste coke is used for fuel. The chimney shaft is 144ft. in height. Dry and wet ashes from middens and a part of the street sweepings are destroyed. About 8½ tons of refuse are consumed per cell per twenty-four hours at a cost for labour and materials of 1s. 7¼d. per ton, leaving a residuum of from 33 to 40 per cent., which is carted to tips or given away. A good deal has to be carted away at a cost of 1s. per ton. About 8440 tons of ashpit refuse are burned per annum, and the annual expenses of working the Destructor are £506 for wages, £223 for repairs, and £74 for sundries. Complaints as to smells have been received, but not recently. The Destructor has no connection with any electric lighting works.

Bury.

The area of the district is 5836 acres, the population about 60,000, and the rateable value £252,452. A portion of the town refuse is dealt with by Destructors and the remainder sent to tips. The Destructor consists of four cells, erected in 1880 by Messrs. Manlove, Alliott, and Co., at a cost of £3600. About 6½ tons of refuse are destroyed per cell per day, leaving a residuum of about 33 per cent. The heat is utilised in the working of a 12-horse power engine for driving two mortar mills. The cost of destroying the refuse is about 1s. 6½d. per ton. The chimney shaft is 180ft. in height, and there is no fume cremator.

Buxton.

The area of the district is 1275 acres, the resident population about 8700, which increases to not less than 15,000 during the "season;" the rateable value is £62,500. The town refuse is destroyed in a four-cell Destructor, erected by Messrs. Manlove, Alliott, and Co., at a cost, including shaft, of £1314 11s. 3d. About 100 tons of ashbin refuse and offal from slaughter-houses are destroyed per week, leaving a residue of 25 per cent. The cost of burning is about 8d. per ton. The annual working expenses amount to about £100. The height of the shaft is 150ft. No cremator is in use, and no complaints of nuisance have been received. No use whatever is made of the surplus heat.

Calcutta.

A four-cell Refuse Destructor was erected here in 1891 by the Horsfall Furnace Syndicate.

Cambridge.

The area of the district is 3278 acres, the population about 37,000, and the rateable value £220,127. Until a comparatively recent date the refuse has been sifted, mixed with night-soil, and sold; but is now destroyed by Destructor. The cost of collection, exclusive of interest on capital and first cost of plant, is 3s. per ton. The amount of house refuse collected per day is 22 tons. In order to make use of the refuse for pumping the sewage, the Destructor was erected on the banks of the Cam, at the outfall end of the main sewer, and adjoins the Gasworks, which is about one mile out of the centre of the town. The Destructor plant consists of six cells of the Manlove, Alliott, and Co. type, with three water-tube boilers, and the furnaces are fitted with Boulnois and Brodie's patent charging tank arrangement. Only four cells and two boilers are in use at one time, and the quantity destroyed per cell per day is about 5½ tons. The object at Cambridge, however, is not to see how much can be consumed per cell, but to get the maximum amount of steam out of the fuel used. The boilers are of the Babcock and Wilcox type, and are placed over and between each pair of cells for generating steam, which is utilised for driving the fan and for pumping the whole of the sewage of Cambridge and Chesterton. The sewage pumping, at the new Sewage Works which adjoin, forms a part of a dual scheme of disposing of sewage and house refuse. The sewage has to be lifted from the outfall sewer and forced through two miles of rising main, against a head of 25ft., on to the Sewage Farm, the total lift being about 48ft. The dry weather sewage flow is about 2,000,000 gallons per day, but the pumps were designed to deal with 5,000,000 gallons as required in case of storms. The heat from the Destructor supplies all the steam required for the purpose, except during the interval between Saturday and Monday, when the cells are not in operation; but a supply of coal is kept on the premises for use in an auxiliary grate, and for supplementing the refuse should it run short, or in the event of extra steam power being required during a heavy storm or other emergency.

The clinkers and ashes from the furnaces drop through a space left at the front of the fire into a closed ashpit, thus heating the forced draught and utilising the whole of the heat in them. They are not withdrawn until practically cold. A portion of the clinkers is used for road-making and similar purposes, but the bulk is tipped to waste. The shaft is 175ft. in height, octagonal with square base, lined with fire-bricks for a height of 50ft., and is 6ft. 6in. internal diameter at the top. The Destructor is 120 yards distant from dwelling-houses. The grate area of each cell is 36 square feet, and the forced draught is produced by means of a 4ft. 6in. diameter fan direct-coupled to a Bumstead and Chandler high-speed engine, which is capable of variation between 200 revolutions and 1100; the average speed is about 400 revolutions per minute.

There are, it will be noticed, two cells to each boiler, and, to avoid loss, the boilers, which are 80-horse power each, are placed as near as possible to the greatest heat. In the working of the Destructor the cells are charged alternately in order that there may be always a bright hot fire in use.

The feed-water for the boilers is obtained from the water mains, and fed through a Webster patent feed-heater, which, by means of the live steam from the boiler, raises the temperature to 160 deg.

There are two 80-horse power tandem compound condensing pumping engines. These, during a period of flood, which lasted twelve hours, were indicated and found to be doing 140-horse power without difficulty in maintaining the steam.

The total cost of the installation, including the boilers and pumping station, was £19,533, the separate items being:—

Buildings for Destructor plant	1,200
Chimney shaft (175ft)	1,600
Destructor cells (six) and including three boilers	7,377
Pumping station buildings	2,132
Engines and pumps	5,324
Land	1,900
Total	£19,533

The cost of labour in burning the refuse is 1s. 3d. per ton. The men work in two shifts of twelve hours each, three men to each shift: one stoker gets 25s. per week and house, value 2s. 6d.; two men, 18s. 6d. per week and house, value 2s. 6d.

Mechanical rocking bars are fitted to the furnaces. The material to be burnt is introduced at the back, and the outlets for the gases are in the sides near the front.

Cardiff.

The area of the district is 8408 acres, the population 160,690, and the rateable value £1,200,000. There are no Destructors in Cardiff at the present time, but the borough engineer, Mr. W. Harpur, M. Inst. C.E., is now engaged upon the design of a refuse disposal scheme on the lines of that in operation at the works of the Refuse Disposal Company at Chelsea.[1]

In a report, dated 27th November, 1894, on the "Disposal of Town Refuse," the Borough Engineer points out that there are several cogent reasons why a change should be made in the present method of getting rid of the refuse of the borough. Formerly, while the town was smaller, there was no difficulty in procuring suitable low-lying land upon which the refuse could be placed within easy distance of the town, and more recently the whole of the collections have been disposed of in raising low lands being formed into parks, pleasure grounds, and river banks, and in reclaiming land at the Dumball's for the purpose of forming timber yards. There will shortly be an end to the disposal of the town refuse of Cardiff by the simple process of tipping it upon low-lying lands within easy distance of the town, and some other process must be resorted to. This is the more certain because of the continuous cry of the pessimist against the use of unscreened town refuse for any purpose whatsoever.

The alternative methods open for the riddance of the Cardiff refuse are (*a*) transportation into the country for agricultural purposes, (*b*) disposal in the sea, (*c*) consumption by fire. The first of these methods the Borough Engineer considers would prove very costly, as the unscreened refuse from a completely sewered town like Cardiff is of very little value for agricultural purposes, and no great demand for it can be anticipated. By adopting this method, therefore, the Corporation would probably be faced with an expenditure of from 2s. to 3s. per load, as is the case with London, for getting rid of the refuse, in addition to the cost of collection.

Excessive cost is also the objection to the second method. Here a wharf would be required where the refuse could be shipped, also one or more tugboats with a fleet of hopper barges to convey the refuse to sea. In addition there would not be the possibility of any return whatever, and the whole of the material would be cast away however valuable.

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[1] For a description of this process see page 73.

The method of burning in Destructors is not only considered a very costly operation, but is looked upon as being a "wholesale destruction of valuable material." The Borough Engineer is of opinion that the capabilities of Destructors, and the value of the products derived therefrom (viz., steam, fine dust, and clinker) have been too often very much over-estimated.

The method of disposal, therefore, considered most suitable for adoption in Cardiff is one of utilisation on the lines already indicated.

Carlisle.

The area of the district is 2028 acres, the population 40,000, and the rateable value £184,437.

There is only a small Destructor in this city for the purpose of burning refuse paper and offal from the slaughter-houses. The surplus heat is not utilised.

Cheltenham.

The area of the district is 4677 acres; the population 48,944; and the rateable value £275,297.

The destructor is situated in a field, six acres in area, adjoining the sewage works. It consists of eight cells erected in 1890—1, by Messrs. Manlove, Alliott, and Co., at a cost of about £6000, which includes the cells, approach road, shaft, two cremators, engine, boiler, and dynamo. The foundations were expensive—being about 16ft. deep. The cremators are rarely used. From four to five tons are destroyed per cell per day, and the cost of labour for burning is 7·6d. per ton. The clinker, which is about 24 per cent. of the bulk dealt with, is used for road foundations and paths, and is valued at from 6d. to 1s. per ton. The shaft is 160ft. high, and is now used partly for the electric light station boilers. The surplus heat is used at the electric lighting station, for grinding mortar, and for working a steam disinfector. Only one small boiler has, so far, been fixed.

Colne.

The area of the district is 5330 acres, the population 23,000, and the rateable value £71,300.

It is proposed to erect two of Messrs. Beaman and Deas' cells. The class of refuse to be dealt with consists of dry ashes, garbage, &c.,

and the ordinary refuse of a provincial town. The anticipated consumption is 24 tons of unscreened refuse per cell per twenty-four hours. The Destructor is not to be laid down in connection with any electric lighting scheme. The height of the shaft will be about 210ft. The estimated cost is £8000, which includes a substantial building for the Destructor, offices, mess-room, &c., engines and mortar mill, and boundary walls. A scheme is under consideration for working the sewage works, sludge presses, &c., from the waste heat by electricity, the works being only 230 yards distant.

Darwen.

The area of the district is 5959 acres, the population 34,200, the rateable value £129,216. The Corporation has recently had the question of the utilisation of the heat obtained by the destruction of the refuse of the borough for the production of power under consideration, and, for the purpose of inquiring into the best practices in vogue, a deputation visited Cambridge, Leyton, Shoreditch, and St. Pancras. As a result of their investigations the Committee were of opinion that under proper conditions, and with refuse of an average quality, there should be little difficulty in obtaining steam varying from 1 lb. to 1¼ lb. per pound of refuse. The Committee had no absolute means of proving this for themselves, as, although steam was being utilised to a very great extent at the places visited, it was not being used to its full capacity, and in nearly every instance it was blowing to waste. Particular attention was directed as to whether any nuisance caused by noxious smells was discernible through the carrying on of the destruction of refuse, but no smell whatever was detected, and from inquiries made at each place visited, it was found that no complaints had arisen on this account.

The Committee, therefore, recommended the principle of combining the erection of Refuse Destructors with the electric lighting plant, and, as regards its application to Darwen, had no hesitation in saying that their refuse was of a superior calorific value to that destroyed at any of the places seen by them, as owing to coal being cheaper there than in the South the same care is not taken in riddling and saving the ashes from the fires for re-use as is exercised in non-mining districts. Assuming that 40 tons of refuse are to be dealt with per day, and, to be on the safe side, assuming its value to be a pound of steam per pound of refuse, they will then be able to command a steam supply of 89,600 lb. of steam per twenty-four hours, or about 3750 lb. of steam per hour, and assuming that 20 lb. of steam be required per H.P., this will give 185 to 190 H.P. per hour for the twenty-four hours, but as even when the trams are run by electricity power will only be wanted for about 16 hours, and for 10 hours of this time the call will not be for more than 200 H.P. per hour, they

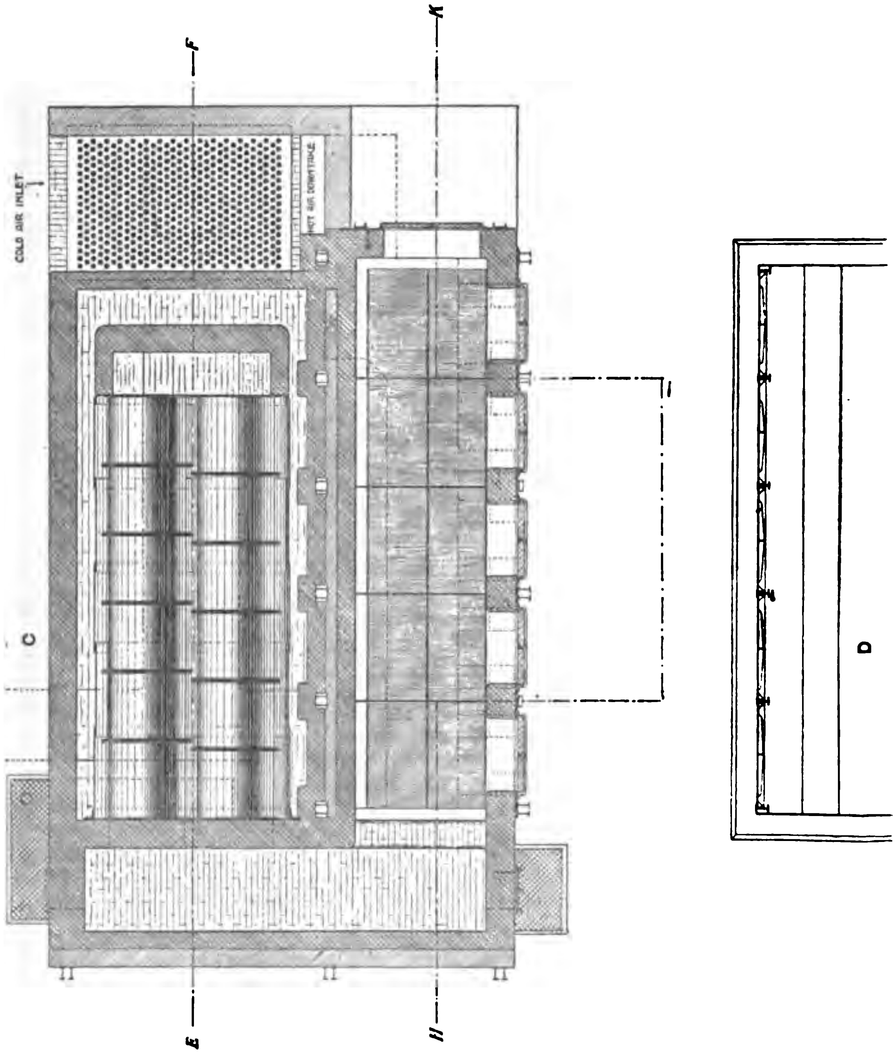

Fig. 44.—Meldrum Destructor—Plan at Level of A B.

would therefore be able to carry over the period of the heavy load by a judicious use of the refuse. In the above the Committee more particularly considered the application of the Refuse for generating sufficient power for the trams as providing a larger and more constant

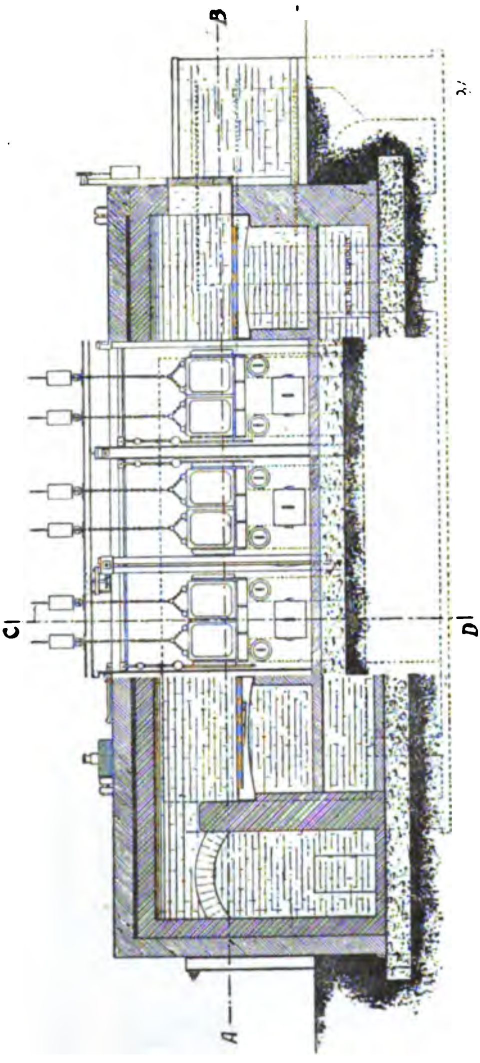

Fig. 45. Meldrum Destructor—Sectional Elevation along H K.

load than the probable lighting demand for some time, and they feel sure that so long as lighting only is undertaken, that for the next few years at any rate, but little coal fuel will need to be purchased.

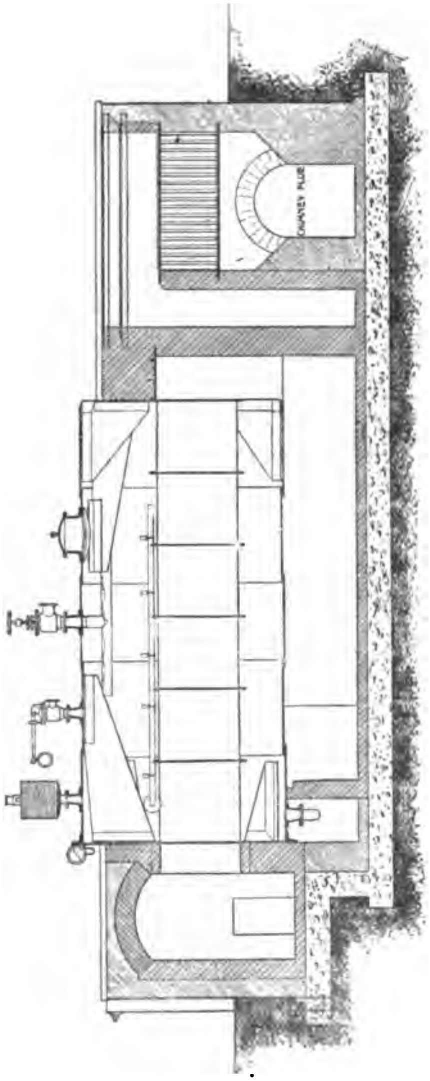

Fig. 6.—Meldrum Destructor—Section E F.

The Committee, from what they saw, were convinced that there is a great future for the adoption of refuse to steam-raising purposes.

Messrs. Meldrum Bros., of Manchester, are laying down eight Destructor cells, with 180 square feet grate surface, and capable of

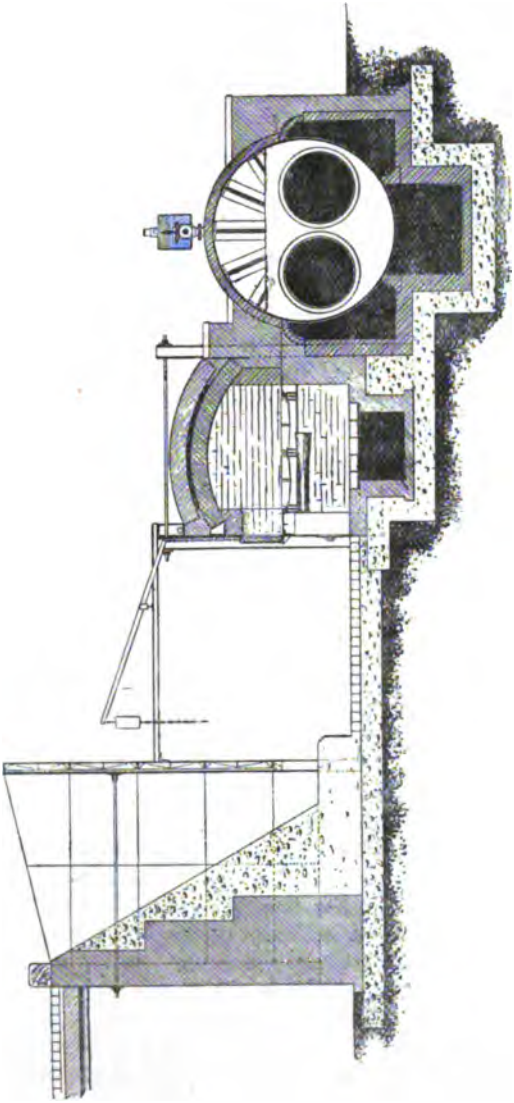

Fig. 47.—Meldrum Destructor Cross Section C D.

burning about 4½ tons of refuse per hour. The accompanying figures (44, 45, 46, and 47) represent the general arrangement and construction of the furnaces, &c. There are two Lancashire boilers, each 30ft. by 8ft., capable of working at a pressure of 200 lb. per square inch.

The Destructor and steam-generation plant, which is being installed in connection with the Darwen electric supply works, embraces the latest improvements of the Meldrum system, and it has been made a special feature here to ensure the production of the maximum possible steam during the period of heavy load. Hence, boilers at the high pressure of 200 lb. per square inch are provided, reduced to 150 lb. at engine, and of large capacity, so as to form a large reserve of power in advance, in readiness for the time when the heaviest demand on the boilers is experienced. After the waste gases have passed through the boilers and ordinary setting, they are still further utilised for heating or regenerating the air for combustion, as shown in the figures, thus giving a temperature of 300 deg. to 350 deg. to the air for combustion. In this way the best results can be obtained from the refuse. Hoppers for the storage of a day's supply of refuse at a point convenient for the firemen are also provided as shown. It is confidently expected that about 2 lb. of steam per lb. of refuse destroyed will be utilised at this installation.

The chimney shaft is 240ft. high, and the cost of the works, which will be the largest of this type yet erected, will be about £5600.

Derby.

The area of the district is 3450 acres, the population 101,770, and the rateable value £420,000. The Destructor consists of six cells, erected by Messrs. Manlove, Alliott, and Co., in 1882, at a cost of £9544, including £1000 for a carboniser, which has since been removed. Six additional cells of Warner's type are now in course of erection. The site occupied by the Destructor is two acres in area, and although there is only one cottage within a quarter of a mile, there are occasional complaints. About 7 tons of refuse are destroyed per cell per twenty-four hours, leaving 33 per cent. of clinker, which is used for filling up low-lying land. The class of refuse to be dealt with consists of ordinary house refuse and trade refuse, but the finer ashes are screened out previous to the refuse being put into the Destructor, and are used for mixing with night soil. Night-soil and ashes are thus mixed for manure and sold at about 1s. per ton. The income from this for 1897 was £746. There is no cremator. The chimney shaft is 160ft. high. The waste heat is not utilised in conjunction with the electric lighting, but is used to work an elevator, and for supplying forced draught to the cells. The boiler for use with heat from Destructor cells is 8-horse power.

Dewsbury.

The area of the district is 1468 acres, the population 29,847, and the rateable value £119,277. The Destructor consists of two cells of the Beaman and Deas' type, which consume about 30 tons per day of twenty-four hours. Four men are employed in two shifts of twelve hours each, and the cost for wages per ton of refuse destroyed is 13·83d.

The two cells are destroying the whole of the town refuse, with the exception of the fish refuse, which is taken to the sewage farm and used as manure. Excreta is sent to farmers, who pay the cost of carriage only. As more than three-fourths of the town is drained by water carriage, and the remainder on the common midden system, the refuse is not much tainted with night-soil. The surplus heat from the Destructor cells is proposed to be utilised in the wheelwright's and blacksmith's shops. About 80-I.H.P. are developed, and a portion is used for forced draught. The chimney is 90ft. in height and 4ft. in internal diameter. The clinker is made into mortar and sold at 7s. per ton.

Dublin.

The area of the district is 3808 acres, the population 245,000, and the rateable value £711,540. The town refuse is partly sifted and sold. There is a four-cell Fryer's Destructor, but, as will be noticed, this is only a small plant, and for the present it is really only on trial. The refuse to be dealt with consists chiefly of contents of ash buckets, is a very light material, and burns freely. The consumption in summer months is about 26 tons per day, but occasionally over 28 tons have been burnt. In winter the average is 22 tons. The residual is about 25 per cent. of the bulk dealt with. About 170 tons of refuse are dealt with weekly at a cost for wages of £7, or 9·9d. per ton.

It is proposed to utilise the waste heat by working a mortar mill. There is one boiler of about 12 H.P. capacity, but the power developed varies with the class of refuse burned. The chimney is 160ft. in height.

These works cost £1575, exclusive of the shaft, which was erected several years ago.

In Dublin the burning of the refuse is not found so cheap as taking it to sea. A Destructor, it is found, requires a good deal of repairs from time to time.

Ealing.

The area of the district is 3225 acres, the population about 32,000, and the rateable value about £200,000. The house refuse is mixed with liquid sewage sludge, and burnt in a Destructor of the Fryer type.

It consists of seven cells and a cremator, erected in the years 1883—5 and '9, at the Sewage Works. The Electric Lighting Installation has also been built at the same site, which has an area of 8 acres. The cost of the cells and chimney shaft was £2400. Four and a-half tons of the above mixture are destroyed per cell per twenty-four hours, leaving a residue equal to 25 per cent. of the bulk dealt with. The cost of burning, including repayment of loan, &c., is 1s. 6d. per ton; but if the value of clinkers, steam, &c., is deducted, this figure is reduced to about 8d. per ton net.

The surplus heat has been utilised since the erection of the Destructor in 1888 for raising steam to work machinery for treating sewage, pumping, &c. It has also been further made use of at the Electric Light establishment adjoining. Sufficient power is obtained from the seven cells, with the combustion of the unconsumed gases in the cremator, to work the day load of about 35-indicated horse power.

Eastbourne.

The area of the district is 5410 acres, the population 44,000, and the rateable value £261,052. The Destructor consists of six cells, erected in 1890 and 1892 from designs of Messrs. Manlove, Alliott, and Co., on a site 1¼ acres in area, at a cost of £3984. There is a cremator, which is in occasional use, according to the direction of the wind. About 30 tons of refuse are collected and burned per day; 2s. 8d. per ton is the cost of collection, and 1s. 4d. the cost of burning. The clinker produced is about 27 per cent. of the bulk tested, some of which is tipped and some sold. The Destructor is close to a vinery and near a main road. Some complaints of smell have been made.

The surplus heat from the cells is applied to the raising of steam (to 60 lb. pressure), which is utilised in the working of air-compressing engines in connection with Shone's Ejectors. Two multitubular boilers are placed one on each side of the main flue.

Edinburgh.

The area of the district is 6166 acres, the estimated population (1897) was 292,364, and the rateable value £2,241,780. A ten-cell Fryer Destructor was erected in 1893 by Messrs. Manlove, Alliott, and Co. The Destructor buildings are designed in the baronial style of architecture, and, together with stabling, yard, &c., cover about an acre of ground. It was intended to divide the city into four districts, with a Destructor to consume the refuse in each, but meanwhile Powderhall was selected as the first, and in some sense, experimental site.[1]

The plant, after being in operation for some time, has now been reconstructed and rearranged by the Horsfall Furnace Syndicate, Limited. The circumstances which led to the conversion will be apparent from the following interesting details of the whole question given in the *Edinburgh Evening News*.[2]

THE POWDERHALL DESTRUCTOR.

At the recent ward meetings several of our town councillors did not mince their language when they had occasion to refer to the city's Refuse Destructor at Powderhall. The Destructor has never been a savoury subject with some members of the Council, but when, after having been in operation for three years, it is stigmatised as a "pest," a "heart-break," and a "white elephant," some inquiry seems to be demanded. Heavy additional expenditure and the non-fulfilment of expectations are the charges laid at the door of the Destructor, but before proceeding to ascertain whether or not the epithets used are justifiable, it will be well to recall the circumstances which led to what one might almost say was the necessity for attempting such an experiment as the Destructor for the disposal of the refuse of the city. For a long time prior to 1893, when the Destructor was erected, Edinburgh was fortunate in being able to reckon upon its refuse as a source of income ; but, partly owing to the depressed state of agriculture and partly to the alterations made in the town, whereby the refuse collected on the streets was lessened in manurial value, a change came over the state of affairs, so that latterly, instead of being willing to pay for the refuse, the farmers asked money for taking it. Thereby, it is said, a loss of several thousands of pounds was caused to the city. But, as Sir James Russell said at the time, though from a practical point of view Edinburgh refuse was destitute of manurial elements, it still contained enough organic matter to make it offensive when stacked in quantity. It will therefore be seen that the Town Council were face to face with a serious difficulty. Destructors had been tried elsewhere, and were deemed satisfactory, why should they not be tried in Edinburgh, was the proposal suggested by way of a remedy for the changed conditions. Bailie Sloan (he was plain councillor then) championed the proposal, and as the first instalment of what was then intended to be the establishment of district Destructors for the city, the building at Powderhall was erected. Lord Provost Sir James Russell at the opening ceremony declared that in his opinion every district was entitled to claim three things in regard to Destructors, namely, there should be no smoke, there should be no smell, and the buildings should be handsome. Though ground has been scheduled for the purpose, the scheme for district Destructors has not yet been accomplished, and Powderhall, the first is as yet the only one, and according to some outspoken councillors is more than likely to be the last.

What then is the position of matters regarding it in respect of the three distinct claims stipulated by Sir James Russell ? Have they been satisfactorily met ? That the buildings are handsome enough will be at once admitted. On the other points the best answer obtainable is provided by the result of the litigation which took place in the Court of Session last year, when proprietors of adjoining land brought an action against the Corporation. After hearing evidence at great length the Court made a remit to, Mr. Hall Blythe, C.E., Edinburgh, and Dr. Odling, Oxford, to prepare a report, and to make recommendations for the better working of the Destructor. In his report Mr. Hall Blyth states that he had visited the Destructor from time to time, and had had several meetings with the parties to the action, and he had also, at the request of parties, visited several Destructors in England. The Edinburgh Destructor, he said, consisted of ten cells, in two rows of five, placed back to back, with the main flue between them. The cells had what was known as a "back exhaust" into the main flue. At the end of the main flue were placed two double cremators, over which the gas was passed. From the cremators the gases could pass directly into the flue leading to the chimney, or if steam was required they passed round the multitubular boiler, thence into a short flue leading to the chimney, which was 185ft. in height. The refuse to be consumed was brought in at the level, on the top of the cells. Each cell was fed from the top by a hole directly over it. The clinker was drawn from the cells on to the floor below. The floor on to which the clinker from the south row of cells was drawn was in direct communication with the open air, and the floor on the north side had a door at each end, one of which, according to the direction of the wind, was supposed always to be shut, but on several occasions he had found both doors open. After the clinker had been drawn into movable iron boxes with lids, a jet of water was played on each for a short time. The boxes were then removed to the bing to the north of the Destructor building. At the date of his first visit there was no forced draught of any sort. With that state of matters the combustion seemed to be imperfect, and the heat for the main flue was not nearly so great as it ought to have been in order to consume the empyreumatic gases. Subsequently the Corporation introduced a steam jet into one of the cells. No doubt that had materially improved combustion in the main flue.

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[1] *The Scotsman.*

[2] October 31st, 1896.

In his opinion the nuisance which had been complained of arose mainly from three causes. First, from imperfectly consumed gases and from dust escaping from the chimney; second, from noxious fumes and dust being blown out of the clinker chamber; and third, from bad smells given off from the feeding chamber owing to the refuse waiting for burning heating while lying on the top of the cells. In order to obviate these matters as far as possible, he recommended several alterations in the apparatus, and in the mode of working. First, that steam jets be introduced into all the cells, which was essential in order to assist combustion and to raise the heat in the main flue to the necessary temperature. Second, that the cells be fitted with a "front exhaust;" at present, after the clinker was drawn from the furnaces the partially-consumed material at the back of the cell was drawn forward, and the back part of the cell was charged from the top with the green material, which immediately began giving off noxious vapours, and these passed directly into the main flue and thence up the chimney. By the adoption of a "front exhaust" the gases from that green material must pass over the burning furnace and round the side of the cell before entering the main flue, and they were thus more effectually consumed. Third, that the feeding chamber be reconstructed and fitted with automatic feeding machines, by which means there was no possibility of the green refuse steaming and stewing on the top of the cells, and the whole place could be kept perfectly clean and free from smell. Fourth, that a large dust chamber be provided between the boiler and the chimney. At present a large quantity of dust escaped from the top of the chimney, and if a proper settling place was provided at the bottom of the chimney, he anticipated that would be largely reduced. Fifth, that the clinker when it was removed from the furnace should not be watered; the watering of the clinker generated sulphuretted fumes. That would necessitate the formation of a concrete platform at the bing behind the building where the hot clinker could be deposited before being tipped on the bing itself. He did not think any benefit would be derived from the use of the cremators, and if the foregoing recommendations were given effect to, he thought they might be removed, but he considered there should still be some length of strongly-heated main flue between the last of the cells and the boiler or the chimney shaft. He had only further to add that, no matter how perfect the apparatus might be made, it would never give proper results unless proper skilled labour was employed and the apparatus was worked with care and intelligence. The men should be trained stokers who thoroughly understood the work to be done and the result to be arrived at. Dr. Odling concurred in all these recommendations, which, he was satisfied, were calculated to effect a substantial abatement of the nuisance found by the Court to have existed.

From that report it will be seen that the Destructor has not been by any means an unqualified success. In fact, the changes recommended amount to nothing less than a reconstruction of the machinery, and upon that it has been resolved to spend £1100. The original cost of the building was about £16,000, and it was computed that, through defective foundations having to be made good, legal expenses, and reconstruction outlays, the total sum spent on the Destructor is now not far short of £26,000. But there is another serious charge against the Destructor. It was originally given out that the cells were capable of consuming between 80 and 100 tons of refuse per day, whereas the actual average has only been between 50 and 60 tons. A story is told, and it is said to be sufficiently vouched for, that, owing to the imperfect combustion in the cells, the body of a cat passed through the Destructor and emerged unsinged. Not only has the quantity of refuse destroyed been under the estimate, but the cost of consumption per ton has very much exceeded the sum stated at the beginning of operations. Tenpence per ton was the figure given then, but last year the cost was 2s. 8½d. per ton. For the past four weeks or more the Destructor has not been working, and meantime the refuse of the city, which averages about 400 tons per day, is being conveyed by rail to a stretch of land some 80 acres in extent in the Pumpherston district at a uniform cost of 10d. per ton from all the loading banks. It should, however, be pointed out that the privilege which the Committee at present have, both as to rate of carriage and place for the disposal of refuse, are exceptional, and have been obtained by negotiation. Of course, in addition to the rate of 10d. per ton, there are the expenses of unloading and distributing the refuse.

In October, 1896, the Horsfall Refuse Furnace Company, Limited, entered into a contract with the Council of the City of Edinburgh for the re-building of the Powderhall Destructor, and undertook to so reconstruct the furnaces that:—

(*a*) No imperfectly-consumed noxious gases or dust should escape from the chimney.

(*b*) No noxious fumes or dust should escape from the clinkering floor.

(*c*) No bad smells should be given off from the feeding chamber from whatever cause.

It was also guaranteed that the furnaces should be capable of burning at least eight tons of ordinary Edinburgh City refuse per cell per twenty-four hours, and that it should be reduced in bulk to at least one-fourth of its original quantity. These requirements, Mr. Hall Blyth reported,[1] have been fulfilled.

The cells were reconstructed upon the Horsfall system, the fume cremators were removed, and in place of them a circular dust catcher of special construction was fixed. The ten furnaces are dealing with about 80 tons of refuse per day, and generating therefrom, with one small boiler, steam for lighting the whole of the premises and the adjoining stables, in addition to the steam necessary for forcing the draught.

Farnworth (Lancs).

The area of the district is 1502 acres, the population 24,000, and the rateable value £73,851. A new type of Destructor, the property of the patentees, Messrs. Ham, Baker, and Co., is in use at Farnworth. It is known as the " Bennett Pythian," and is the only one of its kind at present in use; but it has been adopted at Southampton, where a Destructor of this type is now being built. The special feature of this furnace is the movable grate. There are three cells side by side, and in these are two travelling grates, each of which fills one cell, and are movable together from end to end of the furnace. When the furnace is in full work, one of the cells is in the highest state of combustion, one end cell is empty, and the other end cell is being clinkered. After this it is charged with fresh refuse, and the grate moved over so that the last charged cell comes into the hot middle cell, while the late contents of that cell have been moved into the previously empty cell for clinkering.

Folkestone.

The area of the district is 2481 acres, the population 25,000, and the rateable value £170,400. The town refuse is sold to contractors for £155 a year. According to the *Surveyor and Municipal and County Engineer* (January 28th, 1898), a Dust Destructor is under consideration.

Gateshead.

The area of the district is 3188 acres, the population 98,486, and the rateable value £296,000. There is not a Destructor for dealing with house refuse, &c., but there is a furnace with a chimney 100ft. high for burning dry refuse, or bedding condemned for further use.

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[1] August 6th, 1897.

Gibraltar.

The Gibraltar Sanitary Commission has a two-cell Fryer Destructor in use. The refuse dealt with includes nightsoil from pails, stable manure, &c. Seven and a-half tons are consumed per cell per twenty-four hours, and the cost of burning (labour and materials) is only 4d. per ton. A scheme for the utilisation of the heat, which is at present wasted, is under consideration, but the distance of the works from the Fortress precludes it being used for electric lighting. The height of the chimney is 90ft. The cost of the works including freight, &c., was £1820.

Glasgow.

The area of the district is 12,311 acres, the population 715,579, and the rateable value £4,531,000. About thirty years ago Glasgow abolished the contractor in its Cleansing Department. "The whole work is directly managed by the municipality, and presents a variety of economical methods in the disposal of all kinds of refuse. The department has dust *destructors* and dust *utilisers*, machines which burn and machines which sift the vast mass of ashes, dust, garbage, refuse, and street sweepings collected every day. The total quantity thus dealt with amounted for the year 1897 to 418,331 tons, or an average of 1337 tons daily.

"The Cleansing Department owns 900 railway wagons, and sells its useful products to farmers in half the counties of Scotland. It owns the estates of Ryding and Maryburgh, which cover an area of 717 acres. It also rents the farms of Fulwood Moss and Hallbrae, which extend to 170 acres. The combined profit on these for year ending 31st May, 1897, inclusive of rents for quarries and farms, was £870. The primary object in acquiring these was to afford a *tip* for unsaleable refuse.

"The Cleansing Department has transferred useless bog land into an agricultural paradise. It has its own railways on its estates; it owns quarries and workshops.

"The manure produced by the sifting and mixing machines brings in a considerable revenue, and is also utilised in feeding the farms. The cost of the Cleansing Department for the year 1897 was £69,057, which is equal to a rate of 3¾d. in the £."[1]

The Destructor furnaces work in connection with the screening and mixing machines, and only the rougher or unsaleable refuse is cremated, so that the furnaces cannot well be compared with Destructors in other towns dealing with the whole of the refuse as delivered.

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[1] The *Municipal Year Book* (Ed. Lloyd, Ltd., London).

There are 39 destructor cells in all, and are at five stations, as follows :—

(1) Crawford-street	Works	11 cells.
(2) St. Rollox	"	10 "
(3) Kelvinhaugh	"	9 "
(4) Haghill	"	5 "
(5) Dalmarnock	"	4 "

The Destructors are not built according to any patent, but were erected by the Corporation from their own designs. At the Haghill Works, which have been recently erected, Messrs. Horsfall's patent blowers were adopted for rapid combustion and high temperature. Each cell is of 56 square feet grate area, and is capable of cremating 6 tons of refuse per night of 10 hours. The cost of burning the refuse is not kept separate from the general working expenses, but is estimated at about 1s. 9d. per ton.

At the Haghill Works the steam derived from the heat of the cells is used for driving the machinery, and also for the generation of the electric light and the supply of the steam jets. A 150-horse power Babcock and Wilcox boiler is in use at Haghill, but the full power required cannot as yet be obtained from the heat of the Destructor furnaces alone, and occasional auxiliary stoking is required. The chimney shaft is 250ft. in height. The cost of these works was about £20,000, including cost of stabling and muster hall accommodation for the district and dwelling-houses for the foremen.

The mode of treating the refuse differs in this city, inasmuch as that on its arrival at the works the refuse is mechanically treated, the finer portions being mixed with soil, &c., and sold as city manure, and only the rougher portions passed on to the furnaces for cremation.

The works were designed: (1) For separating the inferior materials from that of manurial value; (2) for reducing the bulk of inferior refuse by burning; and (3) for the mixing of the manure in such a manner as to form a good fertiliser.

The works at Kelvinhaugh are the most complete of the three depôts. The works comprise three floors, viz.:—(1) The top floor, where all the refuse brought in is deposited; (2) the middle floor, where the machinery for manipulating same is placed; and (3) the ground floor, upon which the Destructor furnaces are placed, and also the railway sidings for loading the manure and refuse into wagons, ready for removal into the country.

The process through which the refuse passes is briefly described in a paper recently read at a meeting of scientific gentlemen at Glasgow, as follows :—

> Carts with refuse from ashpits and bins on arriving at the works pass over a weighing machine, the weight and time of arrival being noted by the weigher.

They then pass on to the tipping floor, which is of iron, supported by iron girders and causewayed. In this floor are various shoots to the flat beneath for the different classes of material. The ashpit refuse finds its way through one of these into a revolving screen, which works in a horizontal position. The finer portions of the refuse pass through the screen into a mixing machine, which also receives a regulated quantity of excrementitious matter from a tank conveniently situated, and also a proportion of sweepings from paved streets. The whole is thoroughly mixed by revolving blades, and falls into railway wagons on the sidings underneath. The rougher portions of the material, which cannot pass through the meshes of the screen, are forced by the revolving process out of the bell-shaped mouth of the screen on to an endless carrier. When passing along this carrier any articles of value, such as iron, meat tins, &c., are picked off and thrown aside. The remainder, chiefly light, useless material, falls from the carrier on to a range of furnaces on a lower level, where men are stationed for the purpose of feeding the furnaces. In this manner all the useless refuse, which formerly rendered the city manure next to unsaleable, is reduced to clinkers, and at the same time a manure is produced which commands a ready sale among agriculturalists.

For the reception in wet weather of road sweepings from paved streets, which is mostly composed of horse droppings, large iron tanks, provided with means for draining off the water, have been constructed, running the depth from the ground floor to the tipping floor. The slurry from paved roads is tipped into these tanks, which when full are allowed to stand for a day or two, when, the water having been drained off, the slop is in a condition that it can be manipulated and mixed with the prepared manure. Mud from macadamised roads is considered of no manurial value, and is tipped direct into wagons for exportation into the country, and used for filling up holes, hollows, &c.

The machinery at the works is started every night upon the arrival of the first load of refuse at the depôt, and continues in motion until the arrival of the last load, about 10 a.m., by which time the whole of the night collection has been dealt with, and shortly afterwards despatched into the country, the time occupied by each load of refuse in its passage through the works only occupying a few minutes.

Upon the completion of the manipulation of the last load of refuse the works are stopped for the day, and nothing remains on the premises of the previous night's collections, and within an hour or so more the railway companies have removed it completely out of the city area.

Of the refuse sent out of the city daily, consisting on an average of 160 wagon loads, or 1080 tons, about 60 per cent. is sold as manure to farmers in various parts of Scotland, while the remaining 40 per cent., which is chiefly the clinker and other unsaleable refuse, is sent to the tips on the farms belonging to the City Commissioners. The Commissioners employ four salesmen and three agents for securing orders for and conducting the sales of manure, for which there is a firm demand, except during sowing and harvest time, when farmers are otherwise busy, and at such times the surplus manure is sent to the farms of the Commissioners.

The clinker and other such refuse is used on the farms of the Commissioners for levelling up hollows and poor and low lands, which when covered to a proper depth with road sweepings from macadamised roads and the manure of the department makes excellent agricultural land, in fact the result has been the conversion of some of the very poorest into some of the very best farm land in Scotland. The City Commissioners have three farms in different railway routes, the aggregate area of land being 761 acres.

Gloucester.

The area of the district is 1666 acres, the population 39,444, and the rateable value £157,811. The house refuse is collected three times a week from every house in the city, and it amounts to about 150 tons per week. It is proposed to provide a four-cell Destructor in connection with the boiler-house of an electric light station. A Provisional Order was obtained in 1896 authorising the installation of the electric light. The consulting engineer is Mr. Robert Hammond, and the Corporation have adopted his report embodying a combined scheme of electric lighting and refuse destruction, at an estimated cost of £40,000. As pointed out by the City Surveyor, the house refuse can only be regarded as an auxiliary, providing about one-quarter of the total horse-power required for the installation. The question of site is also found to be one of some difficulty, the combination practically condemning many excellent sites near the centre of the city. A Committee, with Mr. R. Read, A.M.I.C.E., the City Surveyor, recently visited all the types of Destructors now in use in England, including that at Leyton. Both the Committee and the City Surveyor "were of opinion that the Leyton Destructor was far in advance of any others they had seen, both for effective working and cleanliness;" but it appears to be "an open question whether so small a quantity of refuse could not be burnt in an ordinary furnace of a water-tube boiler, or some modification thereof, as a part of the boiler-house scheme, without going to the great expense of special Destructor furnaces." The possible danger of dust getting into the engine and dynamo-house, as at some similar combinations, may be overcome by proper planning.

Govan.

The area of the district is 1070 acres (land), the population is about 70,000, and the rateable value about £250,000. The Destructor consists of eight cells, erected by Messrs. Goddard, Massey, and Warner—six in 1892 and two in 1894. The refuse to be dealt with is heavy and difficult to burn. The quantity consumed is 4·8 tons per cell per twenty-four hours. The cost of burning is 1s. 6·6d. per ton, including gas, water, coals, taxes, and wages. As regards the use to be made of the surplus steam, no definite scheme has been decided upon as yet, but the flues have been arranged so as to accommodate a boiler and engine.

The height of the shaft is 120ft., and the cost of the works, exclusive of site, £6346.

Great Yarmouth.

The area of the district is 3567 acres, the population 51,000, and the rateable value £175,000. The refuse has been utilised in making up recreation grounds, but a Destructor is now about to be built. It will consist of ten cells, by Messrs. Manlove, Alliott, and Co. The class of refuse to be dealt with consists of privy emptyings, market garbage, and house refuse, all of which is very poor in quality. Boilers of about 70-horse power will be installed for generating steam from the waste heat of the cells. The steam will be applied to the lighting of the works by electricity and to the driving of a fan for forced blast and pumping. The shaft is to be 200ft. in height. The total outlay, exclusive of site, will be about £12,000; but the foundations on which the building is to stand are very bad, and are therefore responsible for quite £1500 of the cost.

Grimsby.

The area of the district is 3120 acres, the population 56,000, and the rateable value £180,000. The question of the collection and disposal of the night-soil and refuse of the borough has recently been under consideration. At the present time the Corporation finds itself practically without any means of disposal of dry refuse, and also has great difficulty in getting rid of night-soil when collected. The present system of collection of night-soil is, it appears, undeniably unsatisfactory, "and certainly no one who has had the misfortune to meet the collectors at work in the streets after about 10 or 11 p.m. will from choice repeat the experience." A Sub-Committee appointed to consider the matter reported, in December, 1895, to the effect that, "though the system has been in practice many years, apparently without much annoyance to anyone, when Grimsby was very much smaller, we must not allow ourselves to overlook the fact (which often appears not to be fully realised) that we now have the health and welfare of fully 60,000 people in our hands—a heavy responsibility surely, and one which we cannot afford to neglect. We have from time to time examined the condition of the night-soil depôt in the West Marsh, and have no hesitation in stating that its existence is a serious menace to the public health. The accumulation of deposit frequently exceeds the quantity stipulated as the minimum by the agreement with the contractors. The proximity of the depôt to dwelling-houses is an increasing danger, whilst from its decentralised position a considerable extent of carting (principally through the town) is rendered necessary. For the last twelve years it has been the practice to deposit dustbin refuse upon a plot of Corporation land adjoining the night-soil depôt, and within a short distance of dwelling-houses. The result has been the accumulation of a vast heap of decaying and offensive rubbish."

As an improvement upon existing conditions, the Committee recommended the adoption of either the Manchester system of pail collection or the Hull system, also that instructions be given to the Surveyor to prepare plans and estimates for a six-cell Destructor, together with a statement of the estimated cost of the works and probable return which might be expected from use of the heat for power purposes. It was estimated that a six-cell Destructor such as would be required in Grimsby, with the necessary buildings, would cost, roughly, about £400 per cell, apart from foundations and chimney shaft, or in all about £4500. The erection of a Destructor has not yet been commenced.

Hamburg.[1]

The Refuse Destructor on the Bullerdeich, Hamburg, is the largest installation in existence, and consists of 36 cells of the Horsfall type, erected in 1895. The installation consists of two entirely separate and symmetrical systems, each of which can be worked independently of the other. This applies to the main flues and boilers, as well as to the furnaces. A connecting-flue is, moreover, provided, by which the gases from all the furnaces may be carried at will either through the right or left-hand boiler installation. The transportation of the refuse is effected by means of specially constructed water-tight iron wagons, containing detachable boxes of 4 c.m. capacity, provided with two double-flap doors at the top for loading and one flap-door at the back for unloading. The 36 furnaces are placed in two ranks, each arranged in three blocks of six, in the large furnace hall. An electric crane runs above each rank of furnaces, which lifts the boxes off the wagons and carries them to the feeding hole of each cell (see Fig. 48). Here the box is tipped up by an electric pulley, and emptied on to the furnace platform.

The feeding of the furnaces, which takes place at intervals of 1½ hours, is effected from the platform, which has a common charging-entrance for every two cells placed back to back (Figs. 49, 50). One workman usually serves six furnaces, and, by means of shovels and special feeding tools, conveys the refuse through the feeding hole on to the front or drying hearth of the furnace. The furnace hands employed in the passages beneath the platform—of which there are four, the two centre ones joining—carry the refuse by means of crooks on to the fire-bars, where it is spread out in a thin layer. Each furnace hand serves three cells.

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[1] From a report of Herr F. Andreas Meyer, City Engineer, Hamburg.

The products of combustion, consisting of clinkers and ash, are removed at intervals of 1½ hours by means of rods and fire-hooks, and transported in wagons to the yard behind the furnace chamber. During the clinkering and fetching of fresh refuse, the forced draught is stopped. The ashpit beneath the grate-bars is emptied every twelve hours.

The gases from the fire, as well as the fumes and gaseous products generated by the action of the heat on the refuse on the drying hearth, pass through holes in a fire-brick arch over the fire into a second cremating chamber above the arch, the walls of which, kept at constant red heat, ignite the gases which are still combustible. From this cremator the gases pass through the flues fixed between the furnaces, and through a chimney branching off perpendicularly, into the main flue, which runs beneath all the cells. The dust carried off from the furnaces is deposited in the cremator and main flue, and is removed twice a week from the former, and once every three months from the latter.

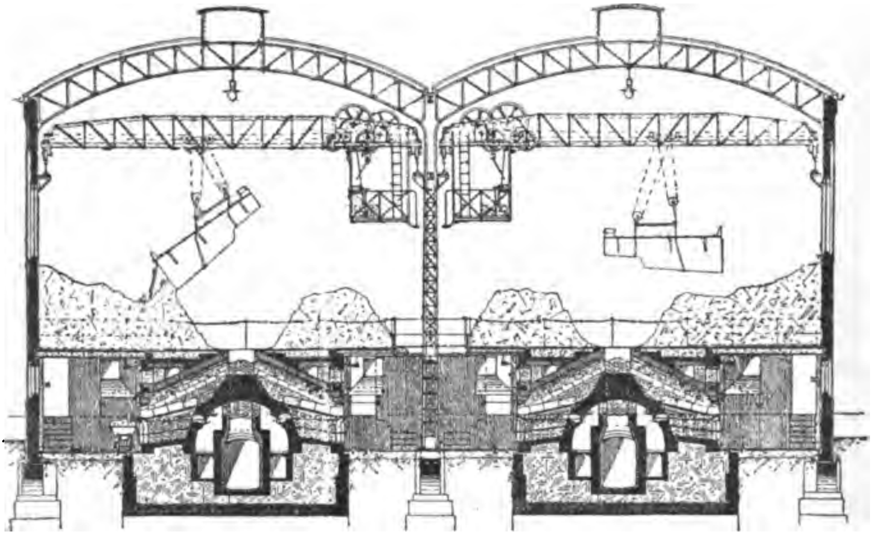

Fig. 48.—Hamburg Destructor—Cross-section of Cells, showing Electric Cranes, &c.

To aid the action of the natural chimney draught, a forced draught was originally supplied by a steam jet, on the principle of the locomotive blow-pipe. The results obtained by this system not being favourable, two centrifugal fans, each coupled with an electric motor in the same axis, were introduced. Each fan serves eighteen cells, and requires about 16-horse power. The air is sucked in in the work tunnels through funnels directly over the clinker doors of the furnaces, and communicating with one common suction tube, so that the smoke and dust are also carried away at this point.

The air conduits lie on either side of the main flue, so that the air to be burnt is already slightly warmed at this point. Between the air conduits of the two sides of the chamber, which may be shut off separately by dampers, there is an additional connecting pipe, so that, if necessary, more than eighteen cells may be supplied by one fan, or either side of the furnace hall may receive air from the fan of the other. From the air pipes beneath the furnaces the air passes through the chamber containing the original steam jet apparatus into the ashpit. An additional air hole leads directly into the ashpit. All three holes may be shut off at the same time. In a new installation the above arrangement could be considerably simplified, the object in this case having been to keep the old steam apparatus intact, in case of emergency. Hitherto, however, the steam jet has never been required since the introduction of the new fans.

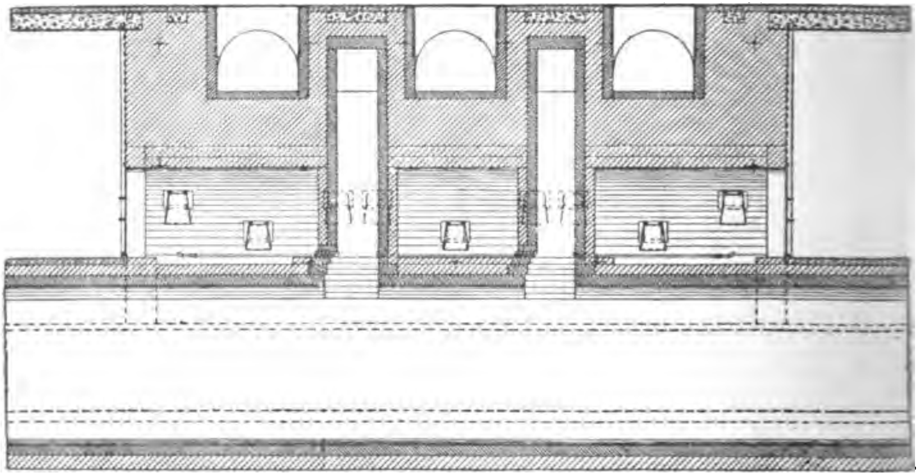

Fig. 49.—Hamburg Destructor—Longitudinal Section through Main Flue, &c.

The main flue passes through the front thoroughfare of the furnace chamber into the boiler chamber. Here two channels, with dampers, are provided for the smoke, so that the hot air can be carried either directly beneath the boilers to the chimney or in a zig-zag line through a bye-pass and thence to the chimney.

Small auxiliary fire-grates are built in the flues immediately in front of the boilers, so that the latter can be heated by direct firing, which is found necessary after lengthy cessations of work.

At the mouth of the two flues in the chimney shown in Fig. 51 a vertical fire-brick bridge is fixed, to prevent the two volumes of smoke meeting in a straight line from disturbing each other.

The steam generated in the steam boilers, with a pressure of six atmospheres, drives the two dynamos of 40-horse power each, standing in the machine-house, which produce the electric energy required for the two electric cranes, the two fans, the clinkering apparatus, and the lighting of the works with 14 arc lamps at 8 ampères and 62 incandescent lamps at 25-candle power. In addition, a loading station for accumulator lamps of the sewer works is fitted up. In the daytime the use of one dynamo suffices; at night both must be kept going. There is, moreover, considerable surplus heat not utilised at present; this is estimated at 100-horse power.

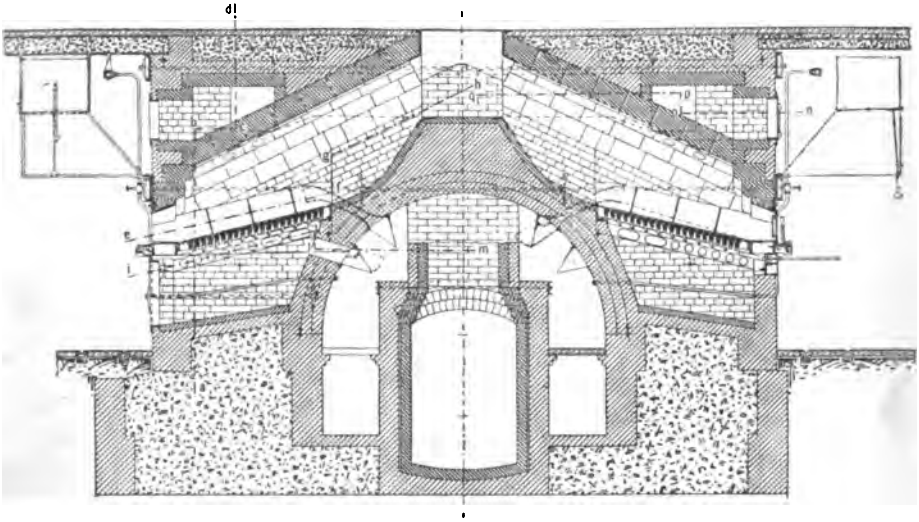

Fig. 50.—Hamburg Destructor—Cross-section through Cells and Main Flue.

The clinker removed from the furnaces is conveyed by means of tip-wagons, first to the cooling apparatus outside the furnace chamber, where it is cooled by water sprinkled upon it from a hose, and thence

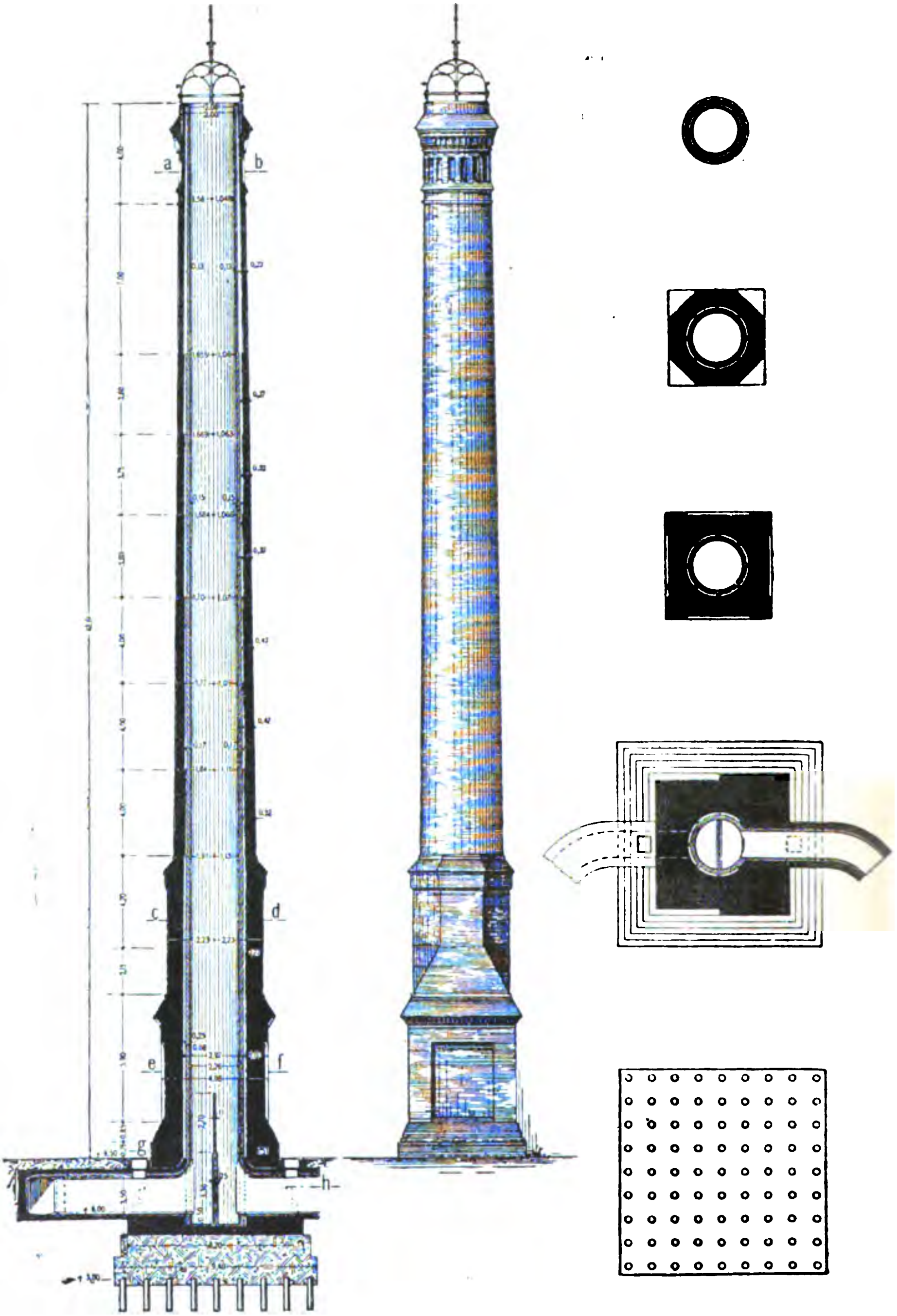

Fig. 51.—Hamburg Destructor—Chimney Shaft.

to the sifting works, where it is emptied into an underground clinker breaker. The broken clinker, which falls from the breaker into a cup, is shaken into a rotating drum-shaped sieve provided with holes of three different sizes, and, thus separated into three kinds, is caught by funnels and thrown into wagons placed beneath. Pieces of clinker which have not been broken up small enough, and bits of metal, are thrown out at one end of the sieve and sorted by hand. The clinker is again broken up, while the metallic substances are put aside for sale. The clinker is used for road and foundation making.

Cost of Construction.

	Marks.	
Foundation	51,000	
Ironwork of furnace chamber	51,000	
Masonry of furnace, machine and boiler chambers	29,000	
Chimney, excluding foundation	17,000	
Machinery and crane, including electric lighting ...	55,000	
Boilers	16,000	
Furnaces	130,000	
Ventilators	11,000	
Clinker apparatus	19,000	
Manager's house	19,000	
Weighing machine and time-box	3,000	
Tool-shed	3,000	
Wagons	30,000	
Miscellaneous	46,000	
Total	480,000	= £24,000.

Products of Combustion.

In English installations the products of combustion are usually recorded as 33 per cent. of the weight, and 25 per cent. of the bulk of the refuse consumed. The Hamburg destructor, on the other hand, produces a residue of 59·5 per cent. of the weight (11·3 per cent. ashes, and 48·2 per cent. clinker), and 40 per cent. of the bulk of the refuse consumed. Similar figures are obtained from Destructors in other German cities.

The character of the material consumed in German cities is therefore presumably different from that of the refuse in this country. Or it may be that the figures recorded from English towns are based upon results obtained from refuse which has been sifted before cremation—the London and Manchester Destructors, for instance.

The clinker obtained is of three qualities, corresponding to the three divisions of the sieve, with holes of 5 mm., 25 mm., and 60 mm. diameter respectively. 16 per cent. of the whole bulk of clinker obtained is of fine, 50 per cent. of medium, and 34 per cent. of coarse quality.

The weight of material per cubic metre is as follows:—

Coarse clinker	800 kilos.
Medium „	840 „
Fine „	870 „
Ash	570 „

The material is sold at 1 Mk. per 1000 kilos. (about 1s. per ton).

The dust which accumulates in the flues is sold for manure, for the manufacture of artificial stones, as filling for the double walls of safes, and the manufacture of asphalt. The old metal found in the refuse is sold at about 7s. per 2000 lb. Nearly 100 tons of metal have been sold at this price in one year.

Cost of Working.

The following table shows the cost of consumption per 1000 kilos. of refuse.

	Mark.
Interest and amortisation of money spent in construction	0·243
Repairs	0·203
Greasing and polishing materials, &c.	0·051
Salaries and wages	1·265
Total	1·762

From this must be deducted earnings from products of combustion, estimated at 0·925 Mk. per 1000 kilos. This brings the cost of consuming the refuse down to 0·837 Mk. per 1000 kilos., or about 10d. per ton.

N.B.—In this calculation the profits which could be derived from the utilisation of the surplus heat are included. This surplus heat was not utilised during the past year, and this, added to other unfavourable circumstances which are now being remedied, raised the actual cost for that year to 1·441 Mk. inclusive, and 1·085 Mk. exclusive of amortisation and interest on building costs. As the cost of carriage of the products of combustion has now been reduced by 1 Mk. per 1000 kilos., a small gain is anticipated in the future.

WORK OF DESTRUCTOR.

The original six trial cells were worked in two ten-hour sections with the customary pauses. It was found, however, that the workmen were not equal to working ten hours at a stretch, and that during the pauses the furnaces were allowed to become too cool. The work, therefore, is now carried on by three gangs, working eight hours each. The fires are kept smouldering from 6 a.m. on Sunday to 6 a.m. Monday, during which time the cells are tightly closed and the chimney draught reduced to a minimum. On Monday morning the boilers are still so hot that 200 to 500 kilos. of coal produce sufficient steam to set the fans in motion, and in less than an hour the fires are completely revived.

Owing to the increased capacity of each cell, the whole of the thirty-six cells are not required for the work, which at times can be done by half the number. Thirty was the maximum number of furnaces required at any time during the past winter.

The earlier experiments with the Destructor showed that each cell consumed 4000 kilos. of refuse in twenty-four hours; the consumption gradually rose to 7500 kilos., and during the winter months (owing to a higher proportion of ashes among the refuse) it fell again to 6500 kilos. From April 1st, 1896, to March 31st, 1897, the Destructor consumed 47,327,693 kilos. of refuse, the average for each cell being 6406 kilos. (or 6¼ tons) in twenty-four hours. From results obtained during the last eight months, an average of 7000 kilos. is anticipated.

The following table shows the temperatures obtained in the main flue directly opposite the entrance to the boiler:—

Highest temperature	760	Centigrade
Average daily maximum	664	,,
Average temperature	580	,,
Average daily minimum	517	,,
Lowest temperature	450	,,

During the employment of the steam draught, the temperature rarely rose above 400 Cent.

The analysis of gases taken from the main flue during the working of the eighteen cells of one-half of the Destructor is as follows:—

	Per cent.
Carbonic oxide	0·03
Carbonic acid	5·00
Oxygen	14·92
Nitrogen	80·05

The chimney draught has a pressure varying between 10 mm. and 15 mm. of water, while the fan creates a pressure equal to about 35 mm. (or 1·37in.) of water. The air on leaving the fan has a pressure equal to from 60 mm. to 70 mm. of water.

Hampstead.

The area of the district is 2248 acres, the population 75,450, and the rateable value £805,443. There are 8 cells of the Fryer type, erected in 1888, and enlarged in 1890. From 5 to 6 tons are burned per cell per twenty-four hours, leaving a residuum of 16 per cent. clinker and 9 per cent. of fine ash. These are used for road-making and for the manufacture of paving slabs. A cremator is in use, and is worked by breeze sifted from dust. The shaft is 120ft. in height. The Destructor men work ten hours a day for six days in the week, changing from day to night shift, and *vice versâ*, every fortnight. The wages are 7d. per hour, and 8d. per hour for the leading man on each shift.

Hanley.

The area of the district is 1768 acres, the population 60,000, and the rateable value £195,214. In November, 1897, the Borough Engineer submitted a report to the Corporation on the question of a site for a Refuse Destructor—all available depôts and "tips" having become practically exhausted. From this report it appears that for the year ending March 25th, 1897, 24,000 loads of ashes were removed to tips at an average cost for cartage of 1s. 8d. per ton; the average distance travelled by each cartload was one mile.

The cost of consuming house refuse by fire at existing Destructors is given as ranging from 9d. to 1s. 9d. per ton. It is also pointed out that "it is now customary for Town Authorities considering the introduction of electric lighting, to unite with that a scheme for the destruction of the town refuse, in the belief that a very great economy would be the result of combining these two operations in one place." For the most part, the Surveyor considers "these matters exist only on paper, and very few places have yet gained any experience on the subject. Numerous schemes have been put forward and advocated. Two have been fully carried out, and are now at work. The first is St. Pancras, where the second Electric Light Station is combined with a Destructor, and the result of last year's (1896) working shows the fuel cost at this station at 1·83d. per unit; but at the first station, where there is no Destructor, it was ·76d. per unit generated"—a result which gives little encouragement for a combined arrangement. The second place referred to is Shoreditch; this being a part of London, and densely populated, with careful working and the assistance of thermal storage, combined with the fact that fuel in London is costly, better results, it is considered, may be expected.

In further reference to the question of a combined undertaking, the Surveyor observes that "the collection of house refuse goes on during the daylight for the most part, and on the other hand, the generation of electricity goes on principally during the dark hours of the evening. Most Destructors work to greater advantage by a steady and regular use of the furnaces or cells, and the use of them could not be limited to the few hours of heavy load at an Electric Generating Supply Works."

The value of Destructors for steam-raising purposes for the generation of electricity is, however, not entirely overlooked, and the Borough Surveyor sees "no reason why the day load electric generator should not be placed at the Destructor, and the current transmitted by high-pressure main to the distributing arrangements at the Electricity Works." It is suggested that one steam engine and dynamo could be removed to the Destructor depôt, where a driver would be in attendance, instead of being at the Electricity Works. Work could thus be practically suspended at the Electric Station for an average of twelve hours out of the twenty-four during the year. The Electrical Engineer believes that any surplus power that may result from the generation of steam at the Destructor depôt over and above that required for the day load could be profitably utilised at the Electricity Works in directly heating water ready for the evening load. The electric energy would be reduced in pressure to 10 volts, and passed through the water contained in a cylinder or reservoir. It is not so much here a question of high efficiency, but of using the surplus steam that would otherwise be thrown away. It is only estimated that something under 100-horse power could be thus transmitted from the Destructor, whilst the total power at present in use at the Electric Works amounts to 1150-horse power.

After considering the question of the suitability of several sites, the Surveyor recommends that called Sandy Finney Farm, to which the refuse of five-eighths of the population could be carted, and the average distance for each cartload would not exceed one mile, as at present. For the remainder of the borough, the following system of collection is recommended. The Corporation are the owners or occupiers of various wharves on the canal. The house refuse could be carted to these points and conveyed by boats belonging to the Corporation to the depôt at the Sandy Finney Farm. Instead of shovelling the ashes into the boats and out again, the following arrangement of skips or boxes is recommended :—Sheet iron rectangular boxes, so made that two or three could fit in an ordinary cart, would be filled at the houses being cleared, carted to the wharf, and there lifted out and placed in the boat, and conveyed to the depôt, at which place they would be again lifted out. The lifting of these skips would be performed by an electric motor, as is done at the Electricity Works in lifting slack out of the coal store or canal boats, and conveying it on to the platform in front of the boilers. This method of using skips in canal boats is also adopted for the coal supply from the collieries to the Manchester Electricity Works.

The house refuse would thus all be conveyed to the site above mentioned and accumulated pending the erection of a Refuse Destructor. Probably also the sludge-cake from the Sewage Works will be conveyed by canal to the same site and burnt in the Destructor.

Hartlepool.

The area of the district is 972½ acres, the population 24,600, and the rateable value £66,500. The provision of a Refuse Destructor is under consideration, and land has already been bought for the purpose of its erection.

Hastings.

The area of the borough as recently extended is 5246 acres, the population about 73,000, and the rateable value £443,605. The town refuse is destroyed in a 4-cell Manlove, Alliott, and Co. Destructor, erected in 1889, at a cost of £4125, on one-third of an acre of ground. There is a cremator, in which small coke is burnt, but it is not continuously in use. About 10,600 tons of rough dust are destroyed annually, at the rate of 36 tons per twenty-four hours, or 9 tons per cell per twenty-four hours. The annual expenses are, approximately, £425 wages, £300 fuel, and £100 for repairs, &c., and the cost of burning is therefore 1s. 6¾d. per ton. Only about 15 per cent. of clinker is produced, and this is used as hard core for roads and paths. The waste heat is used for pumping and for working a Washington-Lyon's steam disinfecting apparatus.

Mr. P. H. Palmer, A.M. Inst. C.E., Borough Surveyor, in a paper[1] on "Some of the Public Works of Hastings," shortly describes the Destructor Works, and from which the following is taken:—The heat and gases generated from the combustion of the refuse are passed through the cremator after leaving the main flue, and then through two steel multitubular boilers of 30-horse power each, to the chimney shaft. The chimney is 130ft. high above ground level, and octagonal in plan, and for a height of 30ft. from the ground line is lined with fire-bricks, with a 4½in. cavity, ventilated to the outer side for the purpose of always maintaining the outer work of the shaft perfectly cool. The base of the shaft is continued below the ground line for a depth of 30ft., and carried on to a foundation of solid sandstone rock, and is constructed of cement concrete, which is upwards of 23ft. square, and contains about 330 cubic yards of concrete. The concrete was filled in continuously until completion, and is therefore practically a monolithic mass. Step irons are built inside the shaft from bottom to top, and the shaft is protected with a copper tape lightning conductor, with rod and crowsfoot 7ft. above the cap. The whole of th flues and furnaces are lined throughout with fire-brick.

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[1] Read before a meeting of Municipal Engineers in May, 1891.

The Destructor, boilers, &c., are built over the sewage tank; the foundation of the shaft is taken through the tank and below the bottom of it, and the arches of the tank have been considerably strengthened under the whole site of works. The steam generated in the boilers is employed for driving a high-pressure horizontal engine, which works the pumps and rams for raising the whole of the salt water used in the borough for street watering, sewer flushing, and the supply to private establishments. The water is raised to the reservoirs at three different altitudes, the highest being situated at Halton, about 270ft. above the engine-house floor, and when pumping to this reservoir the engine is working up to 35·7-indicated horse power. By using the waste heat from the Destructor, I have been enabled to entirely put out of use the two Lancashire boilers which were used for generating steam for salt water pumping, which has saved an annual cost of about £200 for coal. The fumes, on leaving the main flue to enter the cremator, have a temperature of about 600 deg. Fah., and on leaving the cremator about 1500 deg. Fah.

Heckmondwike.

The area of the district is 697 acres, the population 9709, and the rateable value about £32,000. The refuse is dealt with in a 3-cell Destructor, erected in 1883 by Messrs. Manlove, Alliott, and Co., at a cost of about £2000. These cells were fitted with Horsfall's patent forced draught apparatus in 1893.

Hereford.

The area of the district is 5031 acres, the population 22,000, and the rateable value £108,113. Some of the town refuse is sold as manure, some deposited in old gravel pits, and a part is now burnt in a Refuse Destructor.

The question of utilising ashpit refuse in the production of the necessary power for pumping and working the machinery at the Sewage Outfall Works had for several years past been under consideration at Hereford; and, in October, 1896, the constantly-increasing difficulty of the disposal of the house refuse became accentuated owing to complaints made of the serious nuisance caused by the accumulation at the existing depôt, which was inadequate in area for the requirements.

Some trials were made in 1894 at the Corporation Waterworks in raising steam with house refuse mixed with small coal as fuel.

Meldrum blowers were fixed to the boilers, and house refuse mixed with small coal in the proportion of one-third and one-half gave the following results :—

	£	s.	d.
(*a*) Cost per million gallons, without the blowers, in 1893—4, using coal only	1	13	2½
Cost by using one-third of refuse with the Meldrum blowers, per million gallons	1	2	2
Showing a saving of	0	11	0½

Representing a total saving of about £195 per annum.

	£	s.	d.
(*b*) Original cost per million gallons	1	13	2½
Cost, with blowers, using one part of ashes to one of small coal	1	4	9
Saving	0	8	5½

Representing £148 annually.

The above results were in spite of a rise in the price of coal from 9s. 9d. to 11s. 8d. per ton, and an allowance was made of 2s. per ton for the sorting and haulage of house refuse.

These experiments led to the application of the "Meldrum Furnaces" to the raising of steam in the existing boilers at the Sewage Outfall Works. The motive power to the pumping engines at these works is supplied by two Galloway's patent steel boilers, 22ft. long by 6ft. 6in. diameter.

The fuel then used was Nixon's small steam coal, mixed with coke, and the average cost for the five years, 1891 to 1896, was £221 1s. 6d. —an expense which it was anticipated might be entirely avoided by the adoption of the Meldrum furnaces as a means of dealing with the house refuse.

Two Destructor furnaces (with four cells) were accordingly erected in 1897 by Messrs. Meldrum Brothers, of Manchester.

Fig. 52 illustrates the Meldrum "Simplex" furnace as fitted at Hereford and Rochdale.

The furnaces are arranged for the destruction of the town's refuse, and at the same time utilising the heat for steam generation, maintaining the same boiler pressure and quantity of steam as formerly given with coal. The furnaces are each 7ft. by 6ft., with dead-plates, about 6in. wide at back and ends, to prevent clinker from adhering to the walls. The net area of each grate is 35 square feet. They are each divided into two smaller grates by means of brick division walls in ashpits, having a cast iron tee-piece resting on it, the top edge of which is level with the fire-bars. Each ashpit has two steam jet blowers, with separate steam connections and regulating valves. By this means it is intended that an evenly-high temperature shall be maintained by careful and systematic firing, one portion of grate being charged when the other is in an incandescent state.

The necessary air for combustion is supplied by means of Meldrum's Patent Steam Jet Blowers, fixed in vertical cast-iron uptakes, and drawing air from the conduit under the ashpit of the furnaces, the air being admitted through a cast-iron grid at one or both ends; this renders the working of the blowers absolutely silent. The roofs of the furnaces are arched from the side walls to the central division walls, there being two arches—the inner one of fire-brick and the outer one of red brick, having an air space of 2in. between them. Behind the bridge of each furnace is the combustion and settling chamber—the boiler flues leading from it; the rivets of the boiler flue are protected by brickwork. The division wall between the two furnaces is arched in the combustion chamber in order that the brick-work for a certain height may be removed to work a single boiler from either furnace, if necessary.

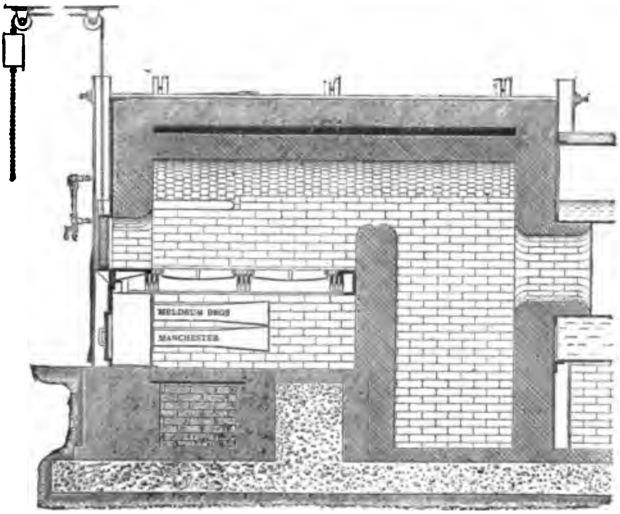

Fig. 52.—The Meldrum "Simplex" Furnace.

The maximum rate of combustion for each furnace may be taken at 18 cwt. per hour; but this, of course, varies with the class of refuse, and an average of 16 cwt. per hour is the amount consumed. The boilers and furnaces may be worked in three different ways:—

(*a*) Both furnaces and both boilers.
(*b*) One furnace and both boilers.
(*c*) Both furnaces and one boiler.

The clinker amounts to about one-third by weight of the refuse consumed; this is made into mortar and sold, and is also found useful for road foundations and making concrete.

The firing is done by hand, and owing to the forced draught a temperature of from 1800 to 2000 deg. Fah. is attained. The installation is considered highly satisfactory, and I am informed by the City Surveyor, Mr. J. Parker, A.M. Inst. C.E., that 1·75 lb. of water is evaporated per lb. of refuse. The steam is used for pumping 1¼ million gallons of sewage daily, working sludge presses, lime mixers, sludge pumps, &c. The cost of burning the refuse is less than 1s. per ton, and a coal bill of £250 per annum is being saved. The two boilers, in front of which the cells are erected, are each 45-horse power; the chimney is only 50ft. in height. The cost of the Destructor Works has been about £800, which includes £325 for supplying and fixing furnaces, £220 for brickwork and foundations, £125 for mortar mill, gearing, &c., and other incidental works and charges.

I am indebted to the City Engineer, Hereford, for the interesting particulars of tests made on the "Meldrum" patent Destructor Furnace, at the City Outfall Works, which appear on the next page.

Test No. 1.—During this test the sludge presses and liming plant worked the whole time. Both sewage pumps worked from 7 o'clock to 10.50, after that one pump only. Steam in excess was allowed to blow off.

Test No. 2.—The sludge presses and liming plant were running the whole time. Both pumps from start to 11.30, then one pump till 3.45, then both again to the finish. Steam in excess allowed to blow off.

Test No. 3.—The sludge presses and liming plant worked the whole time of test. Two pumps worked from 7 o'clock to 11.20, then one pump for the remainder of the time. Steam in excess allowed to blow off.

Hornsey.

The area of the district is 2809 acres, the population 65,000, and the rateable value £425,000. The whole of the house refuse is dealt with by Destructor, and about 10,000 tons are collected per annum, at a cost of 1s. 2d. per load. Any load of less weight than 25 cwt. is not paid for.

The Destructor consists of twelve cells of the type known as Warner's "Perfectus," as manufactured by Messrs. Goddard, Massey, and Warner, of Nottingham. The Destructor (six cells) was erected in 1889, but has been enlarged by four additional cells in 1893, and two in 1895. The elevation of the district varies considerably (from 100ft. to 200ft.), and the Destructor had to be placed in a low part of the district with a view to save cartage, so that any slight nuisance would be certain to be observed in the higher portions of the district

HEREFORD TESTS (*see page* 260.)

Question.	Test No. 1.	Test No. 2.	Test No. 3.
1. Date of test	May 4th, 1898	May 5th, 1898	May 6th, 1898
2. Duration of test	10 hours (7 a.m. to 5 p.m.)	10¼ h. (7.15 a.m. to 5.30 p.m.)	10 hours (7 a.m. to 5 p.m.)
3. State of weather	Steady rain to 8.30, when it cleared	Fine at start, commenced to rain at 1, and continued to end of test	Fine all day
4. Kind of fuel burned	Unscreened ashpit refuse	Unscreened ashpit refuse	Unscreened ashpit refuse
5. Total weight of fuel burned ...	19,768 lb.	19,012 lb.	19,712 lb.
6. Weight burned per hour ...	1,976 lb.	1,855 lb.	1,971 lb.
7. Weight burned per square foot of grate area per hour ...	54·88 lb.	51·52 lb.	54·75 lb.
8. Total weight of clinker and ash	6,699 lb.	6,804 lb.	5,040 lb.
9. Percentage of clinker and ash	33·88 per cent.	35·7 per cent.	25·56 per cent.
10. Percentage of moisture	24·5 per cent.	27·0 per cent.	25·0 per cent.
11. Total water evaporated	26,254·58 lb.	25,570 lb.	29,800 lb.
12. Water evaporated per hour...	2,625·45 lb.	2,494·63 lb.	2,980 lb.
13. Water evaporated per lb. of refuse, actual	1·32 lb.	1·34 lb.	1·51 lb.
14. Water evaporated per lb. of refuse, from and at 212 deg. Fah.	1·58 lb.	1·60 lb.	1·82 lb.
15. Temperature of feed-water ...	48 deg.	48 deg.	48 deg.
16. Average steam pressure... ...	70 lb.	70·2 lb.	70·92 lb.
17. Average steam pressure at blowers	64·37 lb.	64·55 lb.	65·21 lb.
18. Average temperature of superheated steam to blowers ...	320·65 deg. F.	319 deg. Fah.	319 deg. Fah.
19. Average air pressure under grates, by water gauge ...	1·45in.	1·37in.	1·82in.
20. Average chimney pull, by water gauge...	⅜in.	⅜in.	⅜in.
21. Average temperature in combustion chamber by copper test	2000 deg. Fah.	2000 deg. Fah.	2C00 deg. Fah.
22. Average temperature of waste gases at chimney base...	25 readings, 611·5 deg.	36 readings, 638·8 deg. Fah.	41 readings, 715·12 deg. F.
23. Average percentage of carbonic acid (CO_2), by Econometer...	25 readings, 15·56 per cent.	39 readings, 16·84 per cent	41 readings, 16·27 per cent.
24. Ditto, ditto, by Orsat apparatus	20 readings, 14·92 per cent.	16 readings, 16·83 per cent.	14 readings, 16·38 per cent.
25. Average percentage of free oxygen (O), by Orsat apparatus	20 readings, 5·40 per cent.	16 readings, 3·54 per cent.	14 readings, 3·74 per cent.
26. Average percentage of carbonic oxide (CO), by Orsat apparatus	20 readings, Nil	16 readings, Nil	14 readings, Nil

where the best houses are situated. Also, the works are in a populous district, houses being built close to the boundary walls, and the entrance is in the High-street, but no complaints have been received. The area of the site is three-quarters of an acre.

The buildings are very substantial in character, and consist of furnace and boiler-house, engine and mortar-mill rooms, two boilers, engines and mortar mill, with octagonal chimney shaft 217ft. high above ground level. The total cost was about £10,000.

Each furnace has two dampers, which are closed before the furnace doors are opened for clinkering, so that cold air is not admitted into the flues during that operation. Steam and air blasts were fixed and used when the cells were first erected, but afterwards discarded, as it was found that the present quantity of refuse could be burnt without them ; a cremator was also erected, but is not used. The temperature in the main flue is 800 deg. Fah., which is reduced after passing through the boiler to 600 deg. Fah.; the waste heat is utilised for generating steam to drive a 12-horse power engine, which works a mortar mill, clinker crusher, and sawing and drilling machinery. The average pressure of steam in the boiler is 80 lb. per square inch, and is at times scarcely sufficient to drive the machinery at the depôt.

There are three flues in parallel lines ; a Babcock and Wilcox boiler is fixed in one, a multitubular boiler in the other, and the third acts as a bye-pass. The Babcock boiler was erected with the works in 1889, but is not now used; the multitubular boiler was fixed about two years later, and is still in use.

The repairs to the furnaces up to the present have been very small, and only one new set of furnace bars have been fixed to the six cells first erected.

The burning is done by piecework, the men being paid 1s. per 25 cwt. for feeding the fires, clinkering, and wheeling clinker to spoil. During June, July, and August the fires are banked up each night; but for the other nine months work is continuous from 6 a.m. Monday to 6 p.m. Saturday. Each cell is capable of burning eight tons of refuse per twenty-four hours.

The residue amounts to 25 per cent. in bulk of the refuse dealt with. The clinker is a fairly good one, and is used for making slabs under hydraulic pressure, which cost 1s. 9d. per superficial yard to make, including cement, and allowing for value of clinker. A new hydraulic machine is being erected for pressing the slabs, when, it is anticipated, the cost will be reduced to 1s. 3d. per square yard. No granite is used with the clinker, and the blocks are extremely hard, well finished, and of even texture.

There is a great demand for clinker, which is readily sold at 2s. per one-horse load at the depôt. It is used by the District Council for many purposes besides the manufacture of paving slabs, *e.g.*, as hard core for the foundations of new streets, as bottom course for concrete or other paving; also a scheme for workmen's dwellings is in course of erection, the whole of the brickwork of which is being built with clinker mortar and the foundations constructed with clinker concrete. The demand for clinker is found to be so great that the Authority cannot provide sufficient for their own requirements.

The cost of labour for destroying the refuse is 9½d. per ton, and, after allowing for repairs, interest, and repayment of capital, and crediting the value of clinker (2s. per load), the total cost of disposal works out at from 1s. 8d. to 1s. 10d. per ton of refuse burnt.

Huddersfield.

The area of the district is 11,852 acres, the population 100,500, and the rateable value £500,000. The refuse is partly disposed of by a Destructor at Hillhouse, where the disposal of night-soil, house refuse, &c., is performed, and part is "tipped."

A 10-cell Destructor was erected in 1891—2, upon a site about one acre in extent, by Messrs. Manlove, Alliott, and Co., at a cost of £7500. About six tons of refuse are destroyed per cell per twenty-four hours, leaving about 33 per cent. of clinker and ash. The cost of burning is 10½d. per ton. There is a fume cremator in which gas coke is used. The chimney shaft is 180ft. in height.

The surplus heat is utilised in generating steam for turning a mortar mill, corn-crushing, and hay-chopping machines, &c.

Hull.

The area of the district is 11,256 acres, the population (1896) 225,054, and the rateable value £832,699. In 1882 the Corporation erected a Fryer's Destructor with six cells, at a cost of £3200, which includes £1968 for Destructor and buildings, £300 for approach road, and £932 for chimney shaft, 180ft. in height. The class of refuse to be dealt with consists of trade refuse and dry ashpit refuse; the trade refuse includes a good deal of condemned or unsaleable fruit, onions, &c., in the importing season. About fourteen loads of 25 cwt. each are consumed per day, and the cost of burning is 1s. 1½d. per load, or 10 8d. per ton. There are no boilers installed for utilising the waste heat, and of which no use is made. The Horsfall forced draught was fixed to the six cells in 1896. The majority of the houses in the locality have small ashpit privies, the contents of which are sold for manure.

Hyde.

The area of the district is 3042 acres, the population 32,000, and the rateable value £109,182. A 4-cell Destructor was erected in 1893 by Messrs. Goddard, Massey, and Warner, on a site under 3 roods in area, at a cost of £4656, which included, in addition to the whole of the buildings and chimney shaft (180ft. high) an engine, boiler, grinding and mortar mills. Each furnace has a grate area of 27 square feet, and is capable of destroying from 5 to 6 tons per day of twenty-four hours. Space has been left in the building for erecting four additional cells, should they be subsequently required. The clinker is used for road-making and mortar-making; that not required for these purposes is disposed of at one of the town tips. The cost of labour in burning the refuse is given at 1s. 2d. per ton. A fume cremator is placed on the main flue, between the furnaces and shaft; there are houses within 250 yards of the works. The average quantity of refuse collected per day is about 20 to 24 tons, and it includes market, shop, and factory refuse, as well as fishmongers' and butchers' offal and refuse. The surplus heat is used for supplementing the steam power to the sewage works and for mortar grinding.

Ilfracombe.

The population of Ilfracombe is about 7700. The house refuse is carted by a contractor to a disused quarry about 1¾ miles from the Town Hall, which in some instances entails carting for a distance of three miles. Here the refuse is screened, and all old pots, pans, tins, bottles, &c., are sorted out and wheeled into a heap. Paper, rags, vegetable matter, &c., are also separated and burnt in a very small chamber, about 8ft. by 5ft. The material passing through the screen, such as ashes, &c., is wheeled into a large heap, where it is allowed to ferment and heat, and farmers and builders cart it away. The price of 3d. per load has until very recently been paid for this material, but the demand for it at the present time is not sufficiently great to command a larger price than 3d. per load, and the storage room of the District Council is not enough for more than one season's material.

Street sweepings are not mixed with the house refuse. A contractor collects the heaps from the streets after they are swept up, and sells the material. He is paid 28s. per week by the Council, who also provide carts. The contractor provides horses, harness, and men.

There are always four house-refuse carts at work, which cost £3 1s. 9d. per week. The wages of the man employed in screening and burning is 28s. per week.

Ipswich.

The area of the district is 8428 acres, the population 57,400, and the rateable value £235,000. The provision of a Refuse Destructor in combination with an electric light installation has recently been under consideration, but has not yet been determined upon.

Johannesburg.

The question of the provision of a Refuse Destructor has recently been under consideration, but there has been some difficulty in obtaining a suitable site, so that tenders have not yet been called for. It is not intended to tie persons tendering to any particular type of furnace, but to ask for tenders for the erection and maintenance for twelve months of a suitable Destructor for destroying the whole of the house and trade refuse of the town in accordance with certain general particulars and requirements drawn up by the Town Engineer, Mr. Charles Aburrow. The Destructors will be kept working both week days and Sundays. The principal points which are desired in this plant include the following:—(1) The complete combustion of the refuse without the aid of fuel. (2) No stewing of the refuse on the platform. (3) No nuisance from the dust or smell. (4) The burning must be complete, so as to effectually prevent vapours of distillatio escaping from the chimney, and causing nuisance to the public either near the works or far away. (5) The Destructor must be economical in working, and the surplus heat must be used to the best and most economical advantage.

Kensington.

The area of the district is 2188 acres, the population 170,465, and the rateable value £2,095,111. Near the Chelsea disposal works is the wharf of the Kensington Vestry, where there is a 2-cell Destructor which was erected in 1894 by Messrs Goddard, Massey, and Warner, and fitted with forced draught, but its use has been discontinued.

Leeds.

The area of the district is 21,572 acres, the population 402,449, and the rateable value £1,420,866. The greater part of the city refuse is burnt in four sets of Destructors of, or converted to, the Horsfall type, erected at the dates mentioned, and at the following depôts :—

Depôt.	Number of cells.	Date of erection.	Type, &c.
Burmantofts(Beckett-street)	6	1876	Fryer's, but Horsfall's forced draught fixed to 14 cells in 1887. (Only 8 cells are worked.)
" "	4	1883	
" "	4	1887	
Armley-road	6	1877	Fryer's, but Horsfall's forced draught fixed in 1894. (Out of 16 cells at Armley-road only 12 are worked.)
"	4	1884	
"	2	1886	
"	4	1894	Horsfall's system.
Kidacre-street	10	1891	" "
"	2	1894	" "
Meanwood-road	8	1895	" "
Total	50		

Some of the older furnaces are of the Fryer type, but have since been modified by the addition of the Horsfall forced draught. Those erected since 1891 are entirely upon the Horsfall system.

The following boilers have been installed for use with the heat from the various Destructors :—

Burmantofts, 200-horse power, Babcock and Wilcox.
Armley-road, 40-horse power tubular boiler.
Kidacre-street, two 200-horse power multitubular boilers, dimensions 15ft. by 10ft., with 216 4in. tubes in each.
Meanwood-road, 200-horse power, Babcock and Wilcox.

The total cost of the Leeds Destructors has been upwards of £48,345. The shafts vary in height from 120ft. to 240ft.; the cost of the latter one, which is at Meanwood-road, was £2250. The great height of this shaft was necessitated by the fact of the Meanwood Works being in a deep valley, with a recreation ground upon the rising ground.

Fig. 58 shows the general arrangement of the Armley-road Destructor, which now consists of 16 cells.

At the Burmantofts 6-cell installation of 1876 there were eight "carbonisers" erected, but these were abandoned four years later on the score of expense.

At *Kidacre-street* the fumes are brought over the hottest part of the fire to the front of the furnace, and escape, in this case, through a large opening about 1ft. 9in. by 1ft. 6in. on each side, instead of by means of several small apertures in the arch, and are thence conveyed by small flues into the large main flue, 12ft. by 9ft., between the two

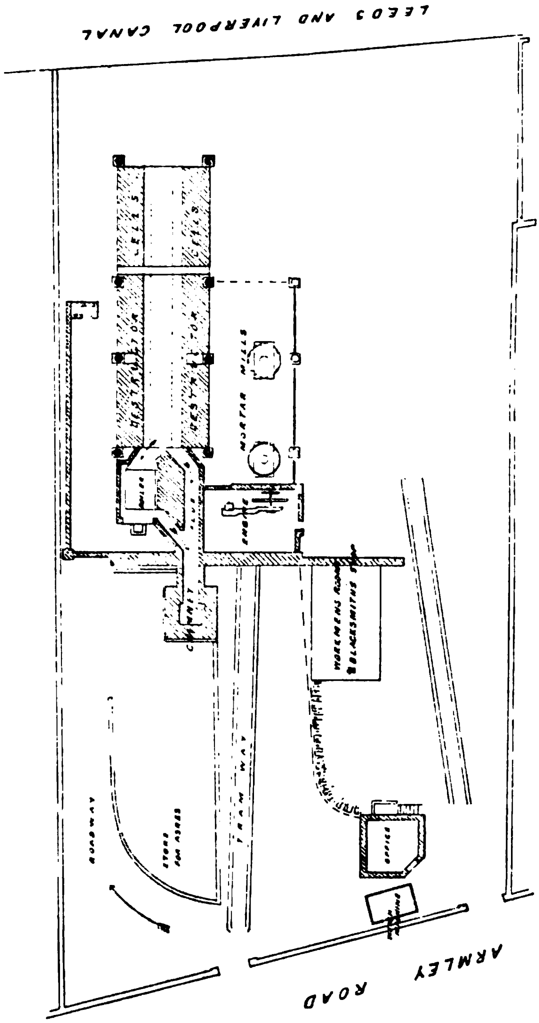

Fig. 53.—Leeds, Armley-road, Destructor.

lines of cells, with a raised platform in the centre about 4ft. wide forming pits 4ft. wide on each side for the dust to collect in. The refuse is fed into the cell through an opening in the top of the arch, over the drying hearth, from which it is raked on to the fire from the front; a similar opening is also made over the front of the fire, through which mattresses and carcases may be placed. The grate area is 30 square feet, and the drying hearth 28 square feet; the steam jets are $\frac{3}{16}$in. in diameter, and blow into air pipes 9in. diameter at each end and 6in. in the centre. The amount of noise made by the steam jets is often objected to. The chimney shaft is 6ft. in diameter and 120ft. in height.

An experiment was made in September, 1891, shortly after the Kidacre-street Destructor was opened, to ascertain, amongst other things, what the difference in temperature was with the steam jets and without, with the following result:—The experiment extended over two periods of twenty-four hours each, similar material being used on each occasion (nineteen hours dry ashpit refuse and five hours wet ashpit rubbish), and temperatures taken hourly. It was found that the ten cells burned 6·2 tons per cell without and 6·7 per cell with the steam jets—the same number of men working in each case. The temperature without the jets averaged 1118 deg. Fah., counting three observations when the pyrometer index touched its maximum as 1500 deg. Fah. With the jets the average was 1464 deg. Fah., but these included seventeen observations, when the pyrometer could register no higher. It is possible that the excess of temperature of 346 deg. Fah. would have been more like 500 deg. Fah. if it could have been registered.[1]

A manager and twelve men are employed, *i.e.*, one man to three cells, working in three shifts of eight hours each. The cells are damped down at 12 o'clock on Saturdays until Monday morning. The men are paid at the rate of 5s. per day, including all holidays. Twelve men in three shifts, from February 4th to February 9th, 1895, inclusive, destroyed about 483 tons of refuse, producing about 182 tons of clinker; the cost of stokers' wages averaged about 9d. per ton of refuse.

The works are situated in a large yard in a populous district; several spaces in the yard are formed into shrubbery beds. The refuse to be dealt with generally consists of about 70 per cent. of dry rubbish, 20 per cent. of night-soil and fish, and 10 per cent. of market refuse. The quantity destroyed per cell per day is about 7 tons, resulting in about 2¼ tons of clinker. The waste heat is utilised to generate steam for driving mortar mills. Mortar is made from the clinkers, mixed with lime ashes, and ground in a mill to the extent of about 100 tons per month; the remainder of the clinkers are carted away to the town tips, or used for road-making.

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[1] *Public Health*, November, 1895. Paper by Dr. J. S. Cameron, M.D., B.Sc., on the "Destruction of Town Refuse by Heat."

The *Meanwood Road Destructor* commenced working on the 1st January, 1896. The grate area of each cell is 35 square feet. Steam is generated in two of Babcock and Wilcox boilers, and is used for driving engines to work the mortar pans, and for the steam jets. The shaft is 240ft. high, 8ft. 6in. internal diameter at the bottom, and 6ft. 6in. internal diameter at the top.

About seven tons are destroyed per cell per twenty-four hours, and 1 lb. of refuse evaporates 1 lb. of water. The temperature attained in the furnaces is from 1800 deg. to 2000 deg. Fah. Six men in three shifts are employed at a weekly wage of 30s., and the cost of labour per ton of refuse burnt is 6·9d.

The cells, which are eight in number, and of the Horsfall type, are arranged back to back, and fed from the top. The material, passing over a bull-nose division to the two sets of cells, passes on to the concave side of an arc of a circle of fire-brick. At the lower part of the curve the material reaches the fire-bars. These are sloped at an angle of about 30 deg., and have an area 7ft. wide by 5ft. long. The walls of the furnace are lined with fire-brick, and just above the bars a strip of iron is fixed, but not in contact with the brickwork, to prevent the clinker from fusing into the latter. The space in front of the fire-bars is closed by two doors. In these are a few apertures communicating with a space between the inner and outer surfaces of the door, thus keeping the latter cool. The space beneath the fire-bars is closed by two iron plates, each pierced by a round hole 9in. in diameter for a steam jet, and leading to a tube 3ft. long. The space between the two iron plates is closed by an iron door. The main flue runs under the centre of the whole arrangement. The bottom of it is a little below the level of the ground in front of the furnaces. The roof is arched, and a pair of flues from each cell enters the main flue with a slight inclination downwards. Each cell has, therefore, two communications (not used by any other cell) with the main flue.[1]

Before erecting the new plant at Meanwood-road, a series of experiments were carried out on the four Horsfall cells erected at Armley-road in 1894. The details of these experiments will be of interest[2] :—

The following conditions apply to all these experiments. The furnaces which, as already said, had a grate area per cell of thirty-five square feet, were in full go, and were clinkered immediately before the commencement of the test. The tipping floor was cleared; all the material placed upon it afterwards was weighed, the material left at the end of the experiment being weighed and deducted from the gross amount placed there. The clinker removed was also weighed, but no computation was made as to the increase or decrease in the amount of flue dust. The experiment lasted for twelve or twenty-four hours, and ended with a clinkering of the cells. The wages were calculated at the rate of 5s. per working day of eight hours. The steam jets (used in all the experiments but one) were two for each cell. Each air aperture is 9in. in diameter, equal for the two to 127 square inches for each cell. The tubes into which the jets discharged are 3ft. long. Beginning, as just said, with a diameter of 9in., they are in the course of 9in. gradually narrowed to one of six, from which size they expand to the original diameter at the other end of the tube. The steam pressure on the jets in each case approximated to 60 lb. per square inch in the boiler.

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[1] *Public Health*, November, 1895.

[2] *Public Health*, November, 1895. Paper on the "Destruction of Town Refuse by Heat," by Dr. J. S. Cameron.

Experiment I. (June 12th, 1894), made with all four cells, for twelve hours, using two jets, each ⅜in. in diameter. The cells were clinkered every two hours. The total quantity burnt was 20·4 tons. The temperature in the side flue, taken hourly, was never less than 1500 deg. Fah.; how much more it is impossible to say. The number of men employed was three[1]; their wages 15s. For each cell in twenty-four hours the quantity consumed was therefore 10·2 tons; the number of men one and a-half; their wages 7s. 6d. The amount of wages paid per ton consumed, neglecting cost of management and interest on plant, was 8·82d. per ton. The clinker weighed 36·5 per cent. of the original refuse.

Experiment II. (June 13th, 1894), made on four cells for twelve hours, without jets, clinkering again every two hours. Quantity burnt, 16·5 tons; average temperature in side flues, 1050 deg. Fah., counting 1500 deg. as the maximum registrable. Men and wages as in the last experiment. Consumed per cell day, 8·25 tons; wages per ton, 10·91d.; clinker left, 35·5 per cent.

Experiment III. (June 25th and 26th, 1894).—Four cells for twenty-four hours; ½in. jets; clinkering every hour. Quantity burnt, 63·1 tons; temperature in the flue frequently enough to melt copper (1990 deg.). Men employed, 12; wages, 60s. Per cell day: Consumed, 15·75 tons, by three men at 15s.; cost per ton (in wages only), 11·41d.; clinker, 35·4 per cent.

Experiment IV. (June 26th and 27th, 1894).—Four cells again for 24 hours; jets, ¼in. (instead of ½in.); clinkering every hour, as in last experiment. Quantity, 60·15 tons; temperature similar; men and wages the same. Amount burnt per cell, 15·04; cost in wages, 11·97d. per ton; clinker, 32·2 per cent.

Experiment V. (June 27th and 28th, 1894).—Four cells for 24 hours; ⅜in. jets; clinkering every hour. Quantity, 54·35 tons; temperature not less than 1500 deg. Fah.; number of men and wages the same. Quantity consumed per cell day, 13·59 tons, at a cost in wages of 13·25d. per ton; clinker, 37 per cent.

Experiment VI. (June 28th and 29th, 1894).—Final experiment, made with only two cells for 24 hours, with ½in. jets; clinkering every half-hour, instead of every hour. The quantity consumed was 53·5 tons; the temperature in the flue repeatedly high enough to melt copper. Number of men employed for the two cells, 12; wages, 60s.; giving an average per cell-day of 26·75 tons, burned by six men at a cost of 30s. in wages. The cost in wages per ton is, therefore, 13·46d. Amount of clinker left was 35·9 per cent.

From the above experiments it will be noticed that by use of steam jets (two ½in. jets, with 60 lb. boiler pressure) and by half-hourly clinkering 26¾ tons of refuse can be burnt by one cell in twenty-four

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[1] Two men working each twelve hours, that is, a day and a-half, and paid 7s. 6d. each.

Experiments on Work Done by Destructor Cells at Leeds, by Messrs. Darley and Putman.

Area of grate bars, 7ft. by 5ft.; jets, two each cell; pressure 60 lb.; wages at rate of 5s. for eight hours.

	Date.	No. of cells.	Duration of experiment.	Dia. of steam jets.	Frequency of clinkering.	Tons burnt.	Temperature of flue.	Men employed.	Wages of firemen.	Per cell day.			Cost per ton burnt. Wages, pence.	Clinker, per cent.
										Tons burnt.	Men employed.	Wages paid.		
				inch.					s.			s. d.		
I.	June 12th, 1894...	4	12 hours	⅛	Every 2 hours	20·4	1500 deg. Fah.	3	15	10·20	1·5	7 6	8·82	36·5
II.	„ 13th, „ ...	4	12 „	No jets	„ 2 „	16·5	1050 deg. Fah.	3	15	8·25	1·5	7 6	10·91	35·5
III.	„ 25th & 26th „ ...	4	24 „	½	„ hour	63·1	Frequently 2000 deg. Fah. *i.e.*, mltd. copp.	12	60	15·78	3	15 0	11·41	35·4
IV.	„ 26th & 27th „ ...	4	24 „	¼	„ „	60·15	Ditto.	12	60	15·04	3	15 0	11·97	32·2
V.	„ 27th & 28th „ ...	4	24 „	⅛	„ „	54·35	1500 deg. Fah.	12	60	13·59	3	15 0	13·25	37·0
VI.	„ 28th & 29th „ ...	2	24 „	½	„ ½ „	53·5	Frequently 2000 deg. Fah.	12	60	26·75	6	30 0	13·46	35·9

hours, six men working at the cell. Such high-pressure working is not economical, as is seen from the last experiment; the wage charge amounted to 13·46 pence per ton burned, also the amount of clinker produced is very high, and the wear and tear on the furnaces must necessarily be unduly great.

The general lesson from these experiments, not carried out for the purpose of exploiting any patent, but merely to test existing plant, is to the following effect:—

The amount consumed per cell increases with the frequency of clinkering, but the cost per ton burned is increased at a more rapid ratio.

The frequency of clinkering can be rendered practicable by increasing the rapidity of combustion. This can be done by steam jets, and the most frequent clinkering and greatest amount burned per cell was accomplished with two ½in. jets at 60 lb. boiler pressure.

The cost in firemen's wages, however, in obtaining these tremendous results (26·75 tons per cell) was nearly 53 per cent. higher per ton burned than when the clinkering was every two hours, and the consumption 10 tons per cell-day.

The wear and tear of the plant is much greater at the higher output, though exactly in what proportion the experiments do not show.

Therefore, the high output method of working the Destructors is not economical.

In considering the question of erecting Destructors, it has to be remembered that the cost of burning is considerable—probably, with sinking fund on plant and everything else, not much under 2s. a ton. Against this has to be put the distance to which the rubbish would have to be carted to a tip. No fuel is necessary, but a large amount of heat is developed, and it would be well so to place a Destructor that this heat could be made available. It is also desirable that the site selected should be so situated as to necessitate as little collar work in carting as possible. Finally, it has to be remembered that the collection of material at the Destructor, and the carting it there, may be itself a nuisance. The daily emptying of ashbins would do much to prevent this.

Leicester.

The area of the municipal borough is 8586 acres, the population 198,659, and the rateable value £781,409.

There are three Destructor stations, the details of which are given in the table on the next page.

The three Destructors are situated on the outskirts of the town, in the form of a triangle, distant about one mile apart, the object being to reduce the cost of cartage. The buildings are in each case of a substantial character.

The town yields about 910 tons of refuse per week, the whole of which, in bad weather of continued frost, can be destroyed by the three Destructors.

Needham-street.—The area of the site is about 2030 square yards. It abuts upon the Midland Railway, and the backs of adjacent artisans' dwelling-houses are less than 100ft. from the tipping baulks by the furnaces. A Board School has also been built since the Destructor was erected in November, 1890. The works consist of a 6-cell Fryer's improved Destructor, with a chimney shaft 160ft. in height. There is also a Jones' fume cremator, but its use has been abandoned, as it was found that by using an improved design of cell, with "Biddle's" model reverse flue underneath, and hand rocking bars, also of Biddle's patent, the heat of the furnaces could be very much increased and better combustion obtained. Cremators are omitted in the subsequent erections, as a temperature of 1800 deg. Fah. can be obtained with natural draught. It is therefore contended that these improvements obviate the use of a cremator, which is also considered costly to use. About 800 tons of refuse per week are destroyed without giving rise to any nuisance to the neighbourhood.

Details of Destructor Stations, Leicester.

Station.	No. of cells.	Date of erection.	Cost of works, exclusive of land.	Height of shaft in feet.	Tons burnt per cell per 24 hours.	Cost per ton of burning refuse.	Type of cell.
			£			d.	
Needham Street	6	1890	6,694	160	9	8·2	Fryer's
Mill Lane	6	1893	8,069	180	9	8·2	Borough Engineer's design.
Lero Works ...	6	1894	8,852	180	9	8·2	Ditto.
Total cells ...	18	costing	£23,615				

A multitubular high-pressure boiler, of about 50-horse power, is fixed between the fume cremator and chimney; and the Corporation supply steam under agreement to a large engineering works adjoining at the rate of about 40-horse power, at £3 15s. per horse-power per annum. Steam is also available for driving a crusher, screen, and mortar mill on the works. Two additional boilers of about 50-horse power each are being put down. A similar increase of boiler capacity is in contemplation at all of the Destructors.

The Corporation did not apply for sanction for a loan to cover the cost of this Destructor, as it was erected as an experiment, and the cost was paid out of current revenue. The undertaking having proved successful, two others were subsequently erected upon a somewhat similar principle. The Corporation found they were obliged to adopt the principle of disposing of towns refuse by fire, as all other means, such as tipping to shoots in sand and clay pits in the neighbourhood, were rapidly becoming exhausted.

The *Mill-lane Destructor* is situated on the banks of the river Soar; the area of the site is about 1800 square yards; there is a webbing factory quite close. The surplus steam drives mortar mills and clinker crushers, and lights the works by electricity.

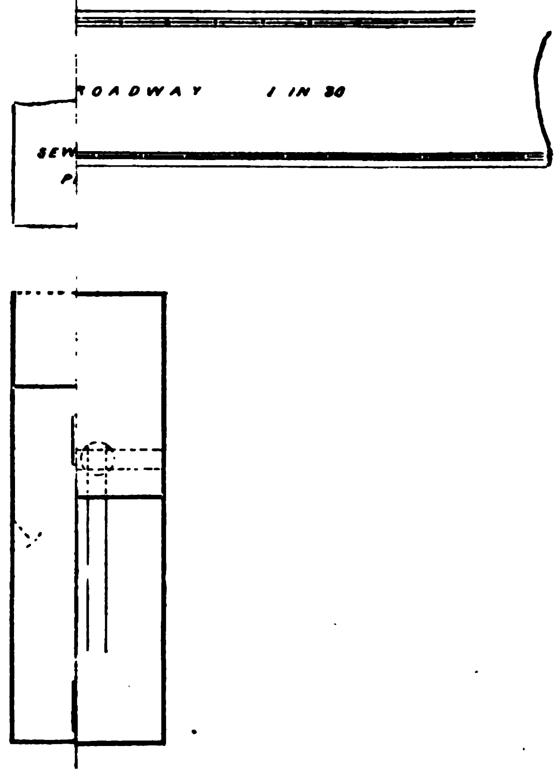
The *Lero Works Destructor* abuts on a large ornamental ground called Abbey Park, and on the side of the Northamptonshire Union Canal; the area of the site is about 4200 square yards. At Lero Works (six cells) there are six men, working in two shifts, at 28s. per week.

In all the Destructors the grate area is 25 square feet. The engineer is of opinion that rocking bars are an advantage as regards burning. A temperature of from 1500 deg. Fah. to 1800 deg. Fah. is obtained in the combustion chambers, and the clinker, which is used for making mortar, concrete, and forming footpaths, &c., amounts to about 33 per cent.; the mortar is sold at 5s. per ton. The last two Destructors were built with mortar supplied from the one first erected. The fires are maintained day and night, with the exception of the period between Saturday and Monday.

Leyton.

The area of the district is 2500 acres, the population 100,000, and the rateable value about £290,000. Some four years ago the Council were called upon to face the question of the disposal of the house refuse and pressed sewage sludge of the district, amounting to about 200 tons of refuse and 150 tons of sludge, or, together, about 350 tons per week.

Until this time both the refuse and sludge had been deposited on waste ground which was then available, but the Council recognised that, in the interests of public health, such a method could not be considered permanent. The disposal of the refuse was, relatively speaking, an easy matter, but the question of burning the sludge in such quantities as were being produced daily was in itself a matter of great difficulty. A committee, however, was appointed to make inquiries as to whether there was a Destructor capable of burning the sludge and refuse combined, and, after visiting various towns where Destructors were established and testing some with Leyton sludge, a contract was entered into with the Beaman and Deas' Syndicate, Limited, of Westminster, who undertook to erect a Destructor which would burn the sludge and refuse in the proportions of one of the former to two of the latter, at the rate of 14 tons per cell per day,



OF THE WORKS.

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without the assistance of fuel, and without causing any nuisance in the process. The total cost of the works was about £7000; this amount includes the iron buildings; eight Destructor cells; two Babcock and

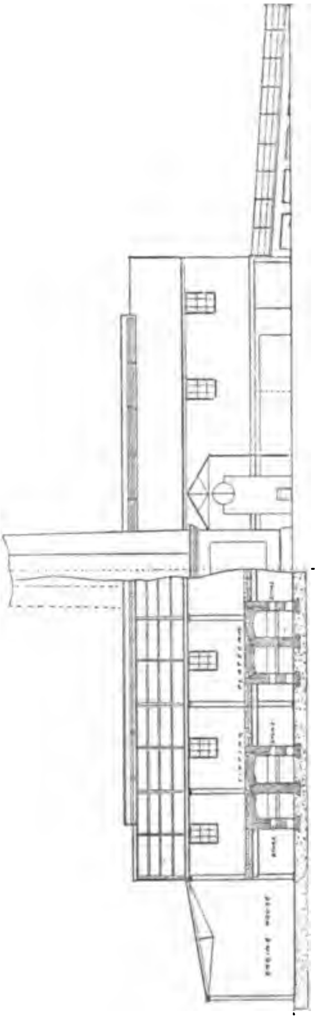

Fig. 56 —Leyton Destructor—Sectional Elevation.

Wilcox boilers, with mountings, &c.; fans, pumps, &c.; two engines, shafting, pulleys, &c.; sludge lift, shafting, trucks, bogies, and gearing; chimney (150ft. above ground level); and approach roadway. Also the erection of weight bridge and office, bath room and mess room drainage, and electric lighting to the buildings and yard. The contract

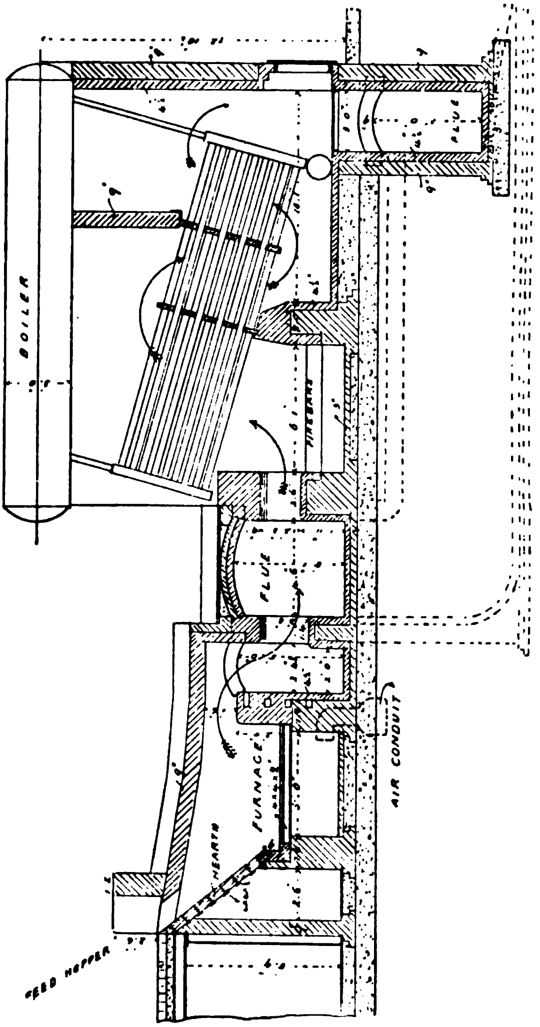

Fig. 57.—Leyton Destructor—Section through Cells and Boiler Setting.

ncluded the working and maintenance of the Destructor for six months after completion, the contractors being allowed to employ their own men, and the Council paying a proportion of the cost of labour. The two Babcock and Wilcox boilers were guaranteed to

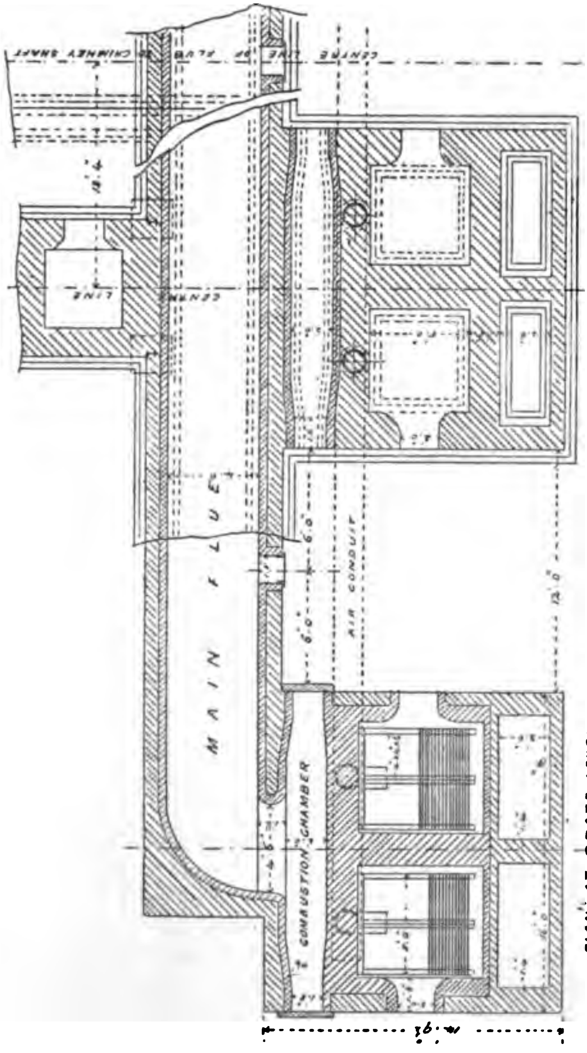

Fig. 58.—Leyton Destructor—Plan of Cells.

produce 50-horse power each. The Destructor commenced work in October, 1896.

The general arrangement of the works, and the construction of the cells and other details, will be apparent from the accompanying figures (Nos. 54 to 59), and need not be described in detail. The plant, as will be seen, consists of eight cells, arranged in four sets of two side by side, and each set is placed so that both cells are charged through a separate hopper from the same shoot off the elevated platform upon which the refuse is tipped from the dust carts. The object of placing the cells in pairs is so that they may be charged alternately in order that the heat may be constant—the organic matter in the fumes from the newly charged cell being fully consumed in the combustion chamber.

The refuse consists of ordinary town house refuse, mixed with pressed sewage sludge (which contains from 60 to 65 per cent. of moisture) in the proportion of two parts of refuse to one of sludge. The fires are first allowed to get red-hot, and are then charged with the proper proportion of sludge cake. The fumes and gases pass over the main fires, and then over a bridge of fire-brick into the combustion chamber, where a further quantity of air is admitted through an air passage in the brickwork, fitted on the outside with a "hit-and-miss" grating, and this, together with the incandescent brick lining, completely destroys all organic matter. About 2 per cent. out of the total refuse dealt with is deposited in the combustion chamber and flues in the form of "fine ash," which is removed at the end of each week, and commands a ready sale at 1s. 6d. per load. There is also

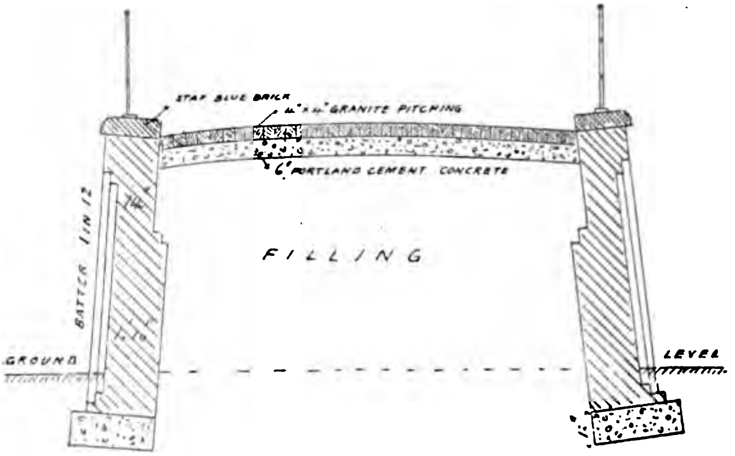

Fig. 59.—Leyton Destructor—Cross-section of Inclined Roadway.

a good demand for the clinker at 6d. per load, and a good deal is used in the district for road-making.

The chimney shaft is 150ft. high above ground line. It is a well-built substantial structure, of plain design, faced with Ruabon bricks, and terra-cotta cornice at junction of octagonal stem, with square base. The foundation is of Portland cement concrete, 7ft. thick and 24ft. square, resting upon a good gravel bottom. The walls reduce 4½in. in thickness at regular intervals, and finish 14in. thick for a length of 25ft. at the top, the upper 20ft. being set in Portland cement mortar. The internal diameter at bottom is 7ft., and at the top 6ft. The shaft is internally protected with a 4½in. Stourbridge fire-brick lining to a height of 75ft. above the level of the floor of main flue at point of junction with shaft. Behind the lining is an air cavity, over-sailed at its upper outlet with fire-bricks. The lightning conductor consists of a ½in. copper rope, about 160ft. long, with platinised copper point, three discharge needles, copper elevating tube, and copper straining bolt for bottom of rope, also with galvanised attachments, insulators, &c. The brickwork at the top of the shaft is secured by an iron cap, fitting like a saddle over the 14in. walls.

The walls of the inclined roadway are as shown in Fig. 59, with a batter of 1 in 12, and are finished at top with Staffordshire blue brick coping, 18in. by 6in., into which strong iron stanchions are caulked 7ft. apart, for carrying three tiers of 1½in. diameter railings. The roadway is paved with 4in. granite cubes, laid on 6in. of Portland cement concrete.

The Destructor buildings are of iron throughout, and are constructed with rolled steel girder columns, with iron trusses to roof, covered with No. 22 gauge galvanised corrugated sheeting. The tipping platform extends the full length of the main building by 20ft. wide over columns 9ft. high to top of floor from ground level, and is formed of corrugated curved steel plates, tarred, resting between longitudinal girders on bottom flanges, covered with concrete, and paved with wood blocks grouted in cement.

The floors of the Destructor buildings, and for a distance of 5ft. all round the outside of same, are formed of 12in. of Portland cement concrete, finished with 1in. of cement rendering.

The boilers, which are of the Babcock and Wilcox make, have a total heating surface of 1098 square feet. The steam and water drum is 36in. in diameter, and 21ft. long, and is made of plates ⅜in. thick, with the longitudinal seams double riveted and provided with a manhole at one end. The boilers are suspended from wrought iron girders resting on four wrought iron columns with cast iron bases, so that the boilers are sustained entirely independent of the brickwork, and free to expand or contract without affecting them. The surrounding brickwork may be removed and replaced, if required, without disturbing the boilers or connections. Each boiler has a 4in. safety valve set to blow at 110 lb. pressure. The water tubes are in seven sections, each consisting of eight best lap-welded wrought iron tubes, 4in. in diameter and 16ft. long, connected at the ends by continuous wrought iron staggered headers. The sections and mud drum were tested and made tight under a hydraulic pressure of 400 lb. per square inch, and the steam and water drum under a hydraulic pressure of 200 lb. per square inch.

The boilers are fitted with separate furnaces for firing with coal, if required, when the Destructor is not in use. The steam is utilised for driving the fans for forced draught, working a hoist for lifting the sludge cake in wagons to the tipping platform level, working a dynamo for lighting the Destructor works, sewage works, and yard, also for driving an air-compressor engine for sewage sludge pressing, and for working machinery at the sewage works for mixing and agitating the precipitants, and for actuating two centrifugal pumps for pumping low-level sewage at the rate of about 1800 gallons per minute—altogether a total duty of about 90-horse power. After the Sunday vacation the boilers are re-started with coal, but when about 50 lb. of steam is registered the ashes are taken out to light the Destructor fires.

Schiele's patent fan (fixed in duplicate) supplies the forced draught at a pressure of about 2in. of water.

In twenty-six weeks—from August, 1897, to January, 1898—5188 tons of house refuse and 3279 tons of sludge were burnt in four cells, working five days per week. That is $\frac{8417 \text{ tons}}{26 \text{ weeks}} =$ 324 tons per week, *i.e.*, $\frac{324}{4} = 81$ tons per cell per week $= \frac{81}{5}$ $= 16\cdot2$ tons of the mixture per cell per day. The cost for labour was 1s. 7d. per ton.

After an inspection of these works, early in 1898, by a Sub-Sanitary Committee from the borough of Tiverton, the Committee, in their Report,[1] stated:—"We were much struck with the cleanly condition of the works and plant and the entire absence of offensive smells, even though the Destructor and the sewage works were so closely connected with each other."

Liverpool.

The city area is 13,236 acres, the population 644,129, and the rateable value about £4,000,000. Nearly the whole of the houses have ashpits attached to them, in which the ashes and other household refuse are deposited.

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[1] Dated February 1st, 1898.

Up to the year 1880 the refuse was disposed of by being barged away along the Leeds and Liverpool Canal, and also by tipping in the vicinity of the city itself; but in the year 1879 the difficulties in connection with the disposal of the unsaleable refuse in this manner became so great that a steam hopper barge, capable of carrying 300 tons of refuse, was obtained, and this vessel went on her first trip in 1880. In the year 1884 a second steam hopper barge, capable of carrying 380 tons, was constructed, and from that year up to the year 1891 about 70 per cent. of the total refuse of the city was conveyed to the sea by these barges to a deposit ground about twenty-four miles from the landing stage, which consists of about 117,000 acres of sea-bottom, at a depth of about 20 to 30 fathoms below the level of low water at spring tides.

In 1891 it was considered desirable that some of the town refuse should be burnt in Destructors, and at the present time there are three Destructor installations in use, as follows:—

Charters-street.—24 cells; 12 cells commenced work in August, 1891, and 12 in August, 1893.

Rathbone-road.—6 cells; commenced working in 1893.

Toxteth Park.—8 cells, two of which were recently added.

A fourth installation of 6 cells is now in course of construction.

CHARTERS-STREET.

These works and depôt are situated on the banks of the Leeds and Liverpool Canal, within a quarter of a mile of the docks, and are surrounded by manufactories, Tate's sugar works, gasworks, chemical works, tallow works, and workmen's dwellings, and warehouses.

This installation consists of two distinct sets of twelve furnaces of the "Fryer" type, erected in parallel rows, with only a cartway between them. The first set (No. 1 Destructor) commenced working in August, 1891, and the second set (No. 2 Destructor) in August, 1893. Each Destructor has its own duty to perform independently of the other, but both pass their products of combustion into one common chamber, and are led away to the chimney by one flue. The Destructors are approached by a double inclined roadway, having a gradient of 1 in 16.

The grate area is twenty-five square feet, and the drying hearth twenty square feet. Two of the cells are fitted with Henderson's patent self-clearing bars, and, it is stated, each cell will destroy about 1½ ton per day more than those adjoining fitted with fixed bars. Each cell consumes from seven to eight tons of refuse, consisting of ashpit, trade refuse, and market garbage, per twenty-four hours. A "Jones' Cremator," burning from twenty to twenty-five tons of coke breeze per week, and costing 6s. 8d. per ton (delivered), consumes the fumes from all the furnaces. The heat from the cells and cremator is used to generate steam in a multitubular boiler 11ft. by 8ft., and is utilised in driving mortar pans, clinker crusher, rocking the furnace bars, lighting the wharf by electricity, and for supplying steam to a Washington-Lyon's disinfector installation. The Destructors are worked continuously from twelve o'clock midnight on Sunday until 6 p.m. on the following Saturday.

No. 1 Destructor is charged by manual labour. All the refuse is tipped from the carts on to the top of the furnaces, and is put into them by men with rakes, shovels, and feeding irons. Destructor No. 2 is fitted with Boulnois and Brodie's patent storing and charging apparatus, by which the refuse is tipped from the carts into the storage tanks, and is dropped from the tanks into the furnaces without being handled by the men.

The charging arrangement consists of a tank or wagon, 5ft. wide by 3ft. deep, and of any convenient length, carried on a pair of rails laid across the top of the Destructor, and moved by one man working a pinion-and-wheel gearing. The tank thus commands two cells. The bottom portion of it is divided into compartments, 2ft. wide, which, when full, represents a charge of 30 cubic feet of material. Each division is provided with a pair of doors, opening downwards, which, when closed, are supported on small wheels, running on a secondary rail. A special charging opening is made in the cell for its full width, namely, 5ft., placed directly over the drying hearth, covered with a fire-brick arch fitted into an open frame, which is easily travelled backward and forward on rails by means of a lever arrangement, so as to open and close the charging opening. This sliding arch is made use of to raise and lower, and to support when closed, the hinged dropping portion of the rail on which the small wheels attached to the doors of the divisions in the tank run. The tank, when empty, is brought under the platform, and filled by tipping the refuse from the scavenging carts directly into it. When one of the furnaces is ready for charging, the tank is run along by the hand gearing to position, bringing a full division immediately over the charging opening; the arch is then rolled back, thus removing the support upon which the hinged portion of the rails rest. These, in turn, support the doors, which fall open, allowing the charge to fall direct on to the drying hearth inside the cell; the arch is then closed, and in doing so raises the hinged rails and the doors to their original position, leaving the cell charged with sufficient material to last from forty-five to sixty minutes, according to the class of material to be destroyed; and the tank is ready to be moved on to the next opening or back to the platform for a fresh supply from the carts as they arrive. This arrangement provides portable storage for a large quantity of material, and entirely does away with the necessity for the shovelling and handling, which is not only very objectionable from a sanitary point of view, but also adds to the cost of destruction.

The introduction of this improved method of charging has, it is stated, effected a saving of 8d. per ton upon the labour involved upon all the refuse consumed in these cells.

The particulars of the labour at the two Destructors are as follows. Each Destructor works in two shifts of twelve hours:—

No. 1 Destructor.

	£	s.	d.
One clinker-man, at 3s. 10d. per day Two clinker-men, at 4s. 2d. „	3	13	0
Eight chargers, at 4s. 2d. „	10	0	0
One man, at 3s. 10d. per day (assisting in unloading carts, and not required at night)	1	3	0
Four firemen, at 5s. per day	6	0	0
Weekly total	20	16	0

No. 2 Destructor.

	£	s.	d.
Two clinker-men, at 4s. 2d. per day One clinker-man, at 3s. 10d. „	3	13	0
Four chargers, at 4s. 2d. „	5	0	0
Four firemen, at 5s. per day	6	0	0
Weekly total	14	13	0

The two chargers in daytime are required to unload carts.

A charge of 2s. 6d. per cart load, and 4s. per wagon load is made for destroying trade refuse papers. The clinker is disposed of by making mortar, paving slabs, and some is barged away. A quantity is also used for making roads through the sewage farms, or other roads or footwalks in outlying districts. A portion of the rough clinker obtained from the clinker crusher is used for foundations of side walks, underground urinals, sewers, and tramway work. Mortar is sold at from 5s. to 8s. per ton, according to quality, and ground clinkers are sold for concrete at 2s. per ton. One of Musker's patent concrete slab machines (Bootle) has been erected for the manufacture of paving from the clinker. The cost of making this paving is 1s. 7¾d. per square yard, and is sold to the Highway Department at about 2s. 6d. per square yard.

Only a small proportion of the total refuse of Liverpool is dealt with by the Destructors. Some is sorted, some sent away direct in canal barges and sold to farmers in the country districts, but the bulk is sent away in steam barges and tipped into the sea some twenty-four miles away. The Corporation are, however, contemplating discontinuing the sending of anything but burnt refuse from the Destructors to sea, in consequence of complaints of the lighter kinds of refuse being washed on to the Welsh coasts.

Old tins, &c., are picked out of the refuse before burning, and these are sold at 1s. 6d. to 2s. 6d. per ton, the purchaser taking them away.

The chimney is 170ft. high, but the City Engineer would advise no Destructor chimney to be less than 200ft. in height, as a very high temperature in the cells is not recommended, and forced draught is not used. It is considered that if the present chimney was larger more work could be done by the Destructors.

Four shower baths have been provided at the works for the use of the men, which are said to be much appreciated by them.

The following is a summary of some of the principal details of the destruction of town refuse at Charters-street, together with particulars of the initial cost of the works, &c.:—

Tons consumed per week, No. 1 Destructor	Average about 470 tons
,, ,, No. 2 ,,	,, 460 tons
Percentage of fine ash left	8 to 9 per cent.
,, clinker left	17 to 18 per cent.
Width of opening between fire-bars (air space)	½in.
Heat generated in cells	900 to 1000 deg.
,, flue, close to cells	900 to 1000 deg.
,, flue, before cremator	600 to 700 deg.
,, cremator	1500 deg.
,, base of chimney	675 deg.
Number of tons of breeze used per week in cremator	20 to 25 tons
Price of breeze per ton	6s. 8d. delivered
Cost of breeze per ton of refuse destroyed	1·8d. to 2·3d. Average 2·08d.
Cost per ton for destruction in No. 1 Destructor, 1895	Total expenses, 1s. 3·05d.
Cost per ton for destruction in No. 1 Destructor, 1895	Labour only, 1s.
Cost per ton for destruction in No. 2 Destructor, 1895	Total expenses, 1s. 0·08d.
Cost per ton for destruction in No. 2 Destructor, 1895	Labour only, 9·10d.
Number of men charging No. 1 Destructor	4 day, 4 night
,, ,, No. 2 ,,	2 day, 2 night
Number of men clinkering No. 1 Destructor	1½ day, 1½ night
,, ,, No. 2 ,,	1½ day, 1½ night
(There are in addition two firemen employed day and night at each Destructor.)	
Quantity of refuse passed through Destructors, 1895	Approximately 48,330 tons
Quantity of clinker, &c., barged to sea, 1895	,, 14,375 tons
Date when No. 1 Destructor commenced	August, 1891
,, No. 2 ,, ,,	August, 1893

Cost of whole Installation.

	£	s.	d.
24 cells, including chimney, inclined cartway, and charging arrangements for No. 2 Destructor	11,488	16	8
Erection of new offices, mess-rooms, baths, and walling	654	8	7
Purchase of land...	1,506	5	0
	13,649	10	3
Installation of electric light, Destructor yard and wharf...	434	2	4
Hydraulic machinery (estimate)	1,620	0	0
	£15,703	12	7

Storage capacity of tanks in tons (6 at 5 tons and 6 at 4 tons)...	54 tons
Sizes of meshes of screens at base of chimney	⅝in.

Chimney.

Diameter at base	8ft. 10in. inside fire-brick lining
Diameter at top	7ft. 6in. inside
Height	170ft.

Type of Destructor... ... ... Messrs. Manlove, Alliott, and Co.'s, Nottingham

TOXTETH PARK (LIVERPOOL).

These Works, together with the Sanitary Depôt of the district, are situated at the south-easterly corner of Sefton Park, on a site forming part of the residential estate formerly belonging to the late Sir Thomas Earle, which, together with the mansion (Richmond Lodge) was purchased a few years ago by the Local Authority for the purposes now used. This being almost a purely residential district of Liverpool, of greatly increasing growth, the works are rapidly being approached on the westerly side by new streets and dwelling-houses of a superior character.

The site of the Destructor buildings was excavated about 7ft. below the level of the adjoining highway, and being surrounded by a high boundary wall, scarcely any portion of the buildings, except the roof and chimney, are seen from the road. The buildings on the site are in five blocks, consisting of the manager's house, an office with weighing machine, and the disinfecting house and laundry; the sanitary stables, workshops, and court-yard (with separate living apartments over the stables, &c., for the horse-keeper and one of the firemen), and the Destructor buildings. The Destructor is of modern construction, and has been in operation since 1895. It consists of eight cells of the Fryer type, two of which have been recently added, with store-rooms, workshop, engine-house, boiler-house, and chimney adjoining. The whole of the buildings have been neatly and substantially built in brickwork, so as not to be an eyesore in that respect to the district. The furnaces are fitted with Boulnois and Brodie's Charging Apparatus, as above described in connection with Charters-street, and Henderson's Patent Rocking Bars. The cost of the works (exclusive of the site, but including excavating the ground as stated), forming shrubbery banks and roads, buildings, cells, chimney, boiler, engine, electric plant and fittings, was about £8000.

The cells are built back to back, with the flue in the centre; the fire-grate, consisting of mechanically-movable fire-bars, as above mentioned, is 25 superficial feet in area; the area of the drying hearth is 20 square feet. The charging apparatus, in addition to effecting a saving in labour, is, it is claimed, also of service where space is limited, and as a means of storage for the refuse (especially at the week ends), for instead of leaving spare refuse lying on the floor, by having duplicate trucks they could be filled and run back underneath the tipping floor until required.

The fumes leave the cell through an opening at the back of the drying hearth, which can be regulated by a door, and which gives access to a small flue leading to the main flue, which is placed partly below and partly between the cells. The gases, on their way to the chimney, pass through a "cremator," and from thence into the boiler chamber. Between the cells and the cremator is a dust pit, formed by a bridge in the flue, to arrest and minimise the quantity of dust passing through the cremator. A screen chamber is also formed in the main flue, a short distance from the chimney, in which there are placed two large screens, which run on wheels, and can be drawn in and out like the clothes frames in a laundry stove. One of these frames has a wire screen of 1in. mesh, and the other a screen of ¾in. mesh. A third screen, with a ½in. mesh, is fixed at the bottom of the chimney. The object of the screen is, of course, to arrest unburnt or charred paper. The heat is utilised to generate steam in a 12ft. by 7ft. tubular boiler, containing 88 tubes 4in. diameter, with a steam chest over. The boiler is capable of being worked up to 80 lb. to the square inch, but is only worked up to 45 lb., as this pressure will work the whole plant, consisting of a 5-horse power engine, which works the rocking bars, capstan, and machinery in the joiners' and mechanics' shop when necessary; also a 14-horse power engine for the electric lighting plant on the premises, besides providing steam for other purposes at the depôt.

No forced draught is used, but the cells are said to burn about seven tons each per twenty-four hours. Clinkers are used for road-making, and old tins are sold at 2s. 6d. per ton. The district is almost entirely on the water-closet system, and the refuse is generally dry and of a very combustible nature. The population of the district (now included in the City of Liverpool) is about 80,000.

The cremator requires about 3½ tons of coke per week. The chimney shaft is 180ft. high, and is 5ft. 6in. in diameter (inside) throughout. The fire-brick lining extends to a height of 90ft. The cost was about £1100.

Three men are employed during the day and two at night; the wages amount to £7 15s. per week. The men work in two shifts of twelve hours each, and the cells are damped down from Saturday noon to Monday morning.

The houses in the immediate neighbourhood of the works are chiefly of a high-class character, standing in their own grounds, and the nearest one is about 180 yards away; the ex-Lord Mayor's residence is 400 yards distant. There have been several complaints of nuisance arising from the works by some of the residents in the neighbourhood, and threats of prosecution have been made, but up to the present no action has been taken.

Llandudno.

The area of the district is 2892 acres, the estimated resident population 9000, and the rateable value £78,716. As regards the removal of house refuse, until October, 1895, the old system of ashpits, most of which were covered, had obtained; but since that date the Council has provided galvanised iron movable receptacles. Each receptacle is 2ft. by 1ft. 3in. by 1ft. 6in., and has a capacity of 3¾ cubic feet; it weighs 35 lb. when empty and about 1 cwt. when full, and is easily handled by two men. The receptacles are cleared periodically, as occasion requires—generally in the winter once a week, and in the season twice a week.

For the disposal of the refuse a 4-cell Beaman and Deas Destructor is being built, in conjunction with works for an electric lighting scheme, and for which the surplus steam will be utilised.

The refuse is of fair quality, and is derived from hotels, lodging-houses, and private houses. In the season about 30 tons per day are collected.

The boiler power installed for use with heat from the Destructor is 152 nominal horse-power; one boiler is fixed to each pair of cells, and there is also one spare boiler to be hand-fired. The chimney is 120ft. in height.

The work is divided up into several contracts, but the cost of the buildings (Electric Light Station and Destructor), chimney shaft, Destructor, and inclined roadway is £5005.

London (City).

For municipal purposes the City area is 650 acres, and it has a resident night population of 37,700 and a daily resident population of over 300,000, while over a million people enter and leave every twenty-four hours.[1]

The City of London has a 10-cell "Fryer" Destructor, erected in 1884, at Lett's Wharf. It burns the paper and dry rubbish collected from shops and warehouses, market refuse, and the refuse material left after the ashes, cinders, and anything else worth picking out have been sorted by women from the contents of the dust carts. The burning capacity of the Destructor is 8·6 tons per cell per twenty-four hours, and the cost of burning, including labour and repairs, is 1s. 8½d. per ton.

The surplus steam is utilised in hoisting the refuse vans to the top of the Destructor, where they are tipped. Chaff-cutting machinery is also driven by the steam from the Destructor.

The cells are arranged back to back over a dust chamber, 10ft. 4in. wide and 6ft. high, the flue from which leads to a multitubular boiler supplying a 30-horse power horizontal steam engine. The chimney shaft is 150ft. high. The cost of the works, excluding site, was £13,811.

There have been complaints of smell, and also of the escape of dust and partially-burned and burning paper from the chimney. The latter was stopped by a grid in the flue.

About 23,160 loads are burned, and the collection is about 41,630 loads. About 20 per cent. of clinker is produced per ton burned, but is of no value.

Londonderry.

The area of the district is 2164 acres, the population 33,200, and the rateable value £83,500. The question of dealing with house and yard cleansing and general street garbage has recently occupied the attention of the Corporation, and the City Surveyor presented an exhaustive report aiming at the project of connecting a Refuse Destructor with the electric light system in order to utilise the combustion of the refuse in the generation of steam; but after careful consideration it was deemed inadvisable to enter upon such a scheme at present. The matter, however, is still under consideration, but has not so far advanced as to enable the details to be given.

Longton.

The area of the district is 1934 acres, the population 36,240, and the rateable value £96,481. There is a Refuse Destructor consisting of six cells, four of which are of the "Fryer" type, and were erected in 1887, and the remaining two were erected in 1895 by Messrs.

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[1] The *London Manual*, 1897-8.

Goddard, Massey, and Warner, of Nottingham, and are fitted with forced draught. The Fryer cells consume about 6¼ tons per cell per day of ordinary house refuse, and the Warner cells more than this quantity; but they are not at present worked up to their full capacity. The cost of burning, including labour and materials, is 11d. per ton; the waste heat generates steam in two 30-horse power boilers, for mortar making and for supplying the forced blast to Warner's cells. The height of the shaft is 150ft.; the total cost of the works, including sheds and other works, was £7840. The fumes pass through a fume cremator.

Loughborough.

The area of the district is 3045 acres, the population 22,000, and the rateable value £75,833. The town refuse is dealt with in a Destructor of novel design, built by Messrs. H. Coltman and Sons, Loughborough. Its general arrangement will be apparent from the three figures (Nos. 60, 61, and 62) annexed.

There is only one cell, and this is capable of dealing with from 12 to 20 tons of refuse per day. The cost of burning is 1s. 2d. per ton. The waste heat generates steam for pumping sewage on to the sewage farm, a lift of 24ft.; also, a small electric installation is worked for lighting the Destructor and the pumping station. The boiler is of 90-horse power; the chimney shaft is 80ft. high, and forced draught is also used.

The following particulars of the works are contained in a paper by Mr. A. S. Butterworth, entitled "Loughborough Sewage and Refuse Disposal Works"[1]:—

"The steam necessary for pumping the sewage is entirely raised by the burning of the ashpit refuse of the town. This is equivalent to an annual saving of £400 or £500, as compared with the cost of coal. It would scarcely be just to set the expenses of burning the refuse against the cost of coal, as the cost of refuse disposal would be the same if conducted independently. Although a certain amount—generally a very small percentage—of the heat produced in the process of refuse disposal in furnaces is utilised in some towns, it seems to be a general opinion amongst engineers that the refuse of a town is of no, or little, substantial calorific value, but that the steam-raising power of the refuse of some towns is worth consideration has proved true at Loughborough, as subsequent figures will prove.

"The Refuse Destructor is situated at the end of the Sewage Works Buildings, and is approached by a high-level road, which runs at a uniform level from the canal bridge—thus avoiding a double incline—

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[1] "Minutes of Proceedings" of the Institution of Civil Engineers, vol. cxxv

and round the front of the buildings, at a height of 13ft., an inclined road leading down to the low level at the rear. This road has been constructed entirely of the ashpit refuse of the town, manufacturers' ashes, and builders' rubbish, well rolled and consolidated, the banks being soiled and turfed. Each road is 15ft. wide, and fenced with iron railings. The Destructor (Fig. 61) is of novel design, and was constructed by Messrs. H. Coltman and Sons, Loughborough.

"In Destructors where it is attempted to utilise the heat, a multitubular boiler is generally placed in the *flue* between the furnace and the chimney. Only a small portion of the available heat is thus utilised. This furnace has been designed with the object of collecting the *direct heat of the furnace itself* [1], as well as that of the escaping gases. The refuse is tipped from the carts into a hopper, from whence the furnace is charged by hand down the shoot. The arrangement of the furnace consists of a water-tube boiler, each of the lower shells being 12ft. by 4ft. 6in., and the upper 12ft. by 5ft. 6in., these being connected by continuous water-chambers (C) and 110 2¼in. tubes—88 outside the water-chambers and 22 in the furnace proper. Between

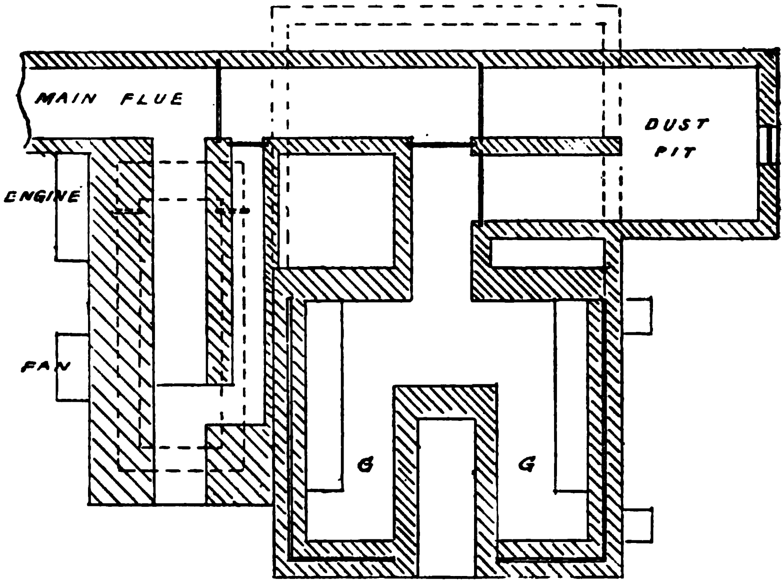

Fig. 60.—Loughborough Destructor—Ground Plan.

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[1] This no doubt accounts for the large quantity of water (2·88 lb.) evaporated per lb. of refuse, as mentioned subsequently.

the two bottom shells is the fire-grate, having an area of 28 square feet, consisting of Perrett bars, 9in. deep, of the shape shown in the figures., the lower 4½in. dipping into a water-bath, the level of which is preserved by a cistern and ball valve. This arrangement keeps the bars cool and prevents the clinker from adhering to the bars; while a forced draught from a 12in. fan, driven by a special 8-horse power horizontal engine is introduced above the water surface, and maintains a high temperature. The bars, being only ⅛in. apart at the grate surface, and the strong upward blast, prevent the dust from falling through; thus a good hard clinker is formed, which is easily removable, and is used for miscellaneous purposes.

"In order to avoid the chilling effect of the surfaces of the boiler upon a newly-spread fire, fire-brick blocks C, easily renewed, are carried on pockets riveted to the bottom cylinders of the boiler, which become white-hot, and radiate upon the green refuse freshly drawn forward. These blocks run continuously in the form of an arch from the back of the furnace to within 18in. of the front. The whole boiler is enclosed in a fire-brick arch. When the furnace is freshly charged from the hopper, the gases from the green refuse have to pass directly over the hottest part of the fire to the front of the furnace; then up, at D, between the end of the fire-brick blocks and the furnace front, and back to the rear along the central flue, E, in contact with all three shells. The water chamber, and the inner tubes, then pass round the rear end of the continuous water chamber, and back along the flues, F F, catching other portions of the shells,

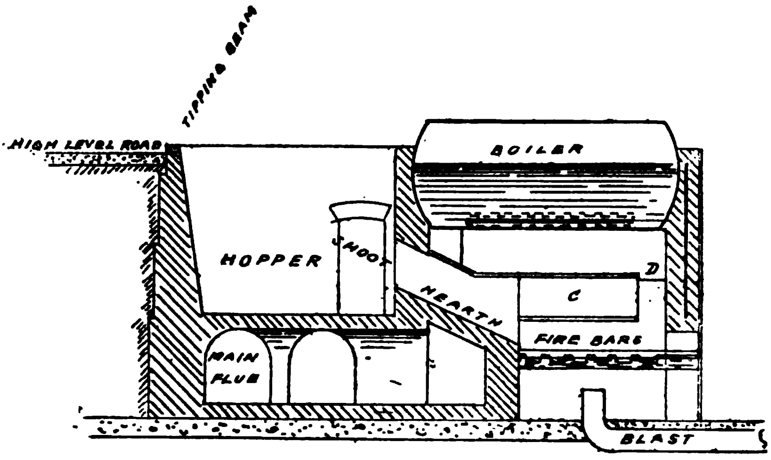

Fig. 61.—Loughborough Destructor—Longitudinal Section.

the water chamber and the outside rows of tubes, down to the flues, G, being in contact with the bottoms of the two lower cylinders. Thence the gases may pass direct to the chimney by the main flue, the chimney being octagonal and 80ft. high, and of an average internal diameter of 4ft.; or they may be diverted and passed through the supplementary multitubular boiler, 10ft. by 4ft. 6in., which is ordinarily thus used as a feed-water heater for the Destructor boiler proper, but is capable of raising sufficient steam from coal fuel to drive the engines when the Destructor is thrown out of work, for boiler inspection purposes. Thus there is every opportunity of utilising all available heat to the fullest extent. At present only one cell has been erected, but it is more than capable of accomplishing the desired work, and of burning much more than the average 8 tons of refuse per day available.

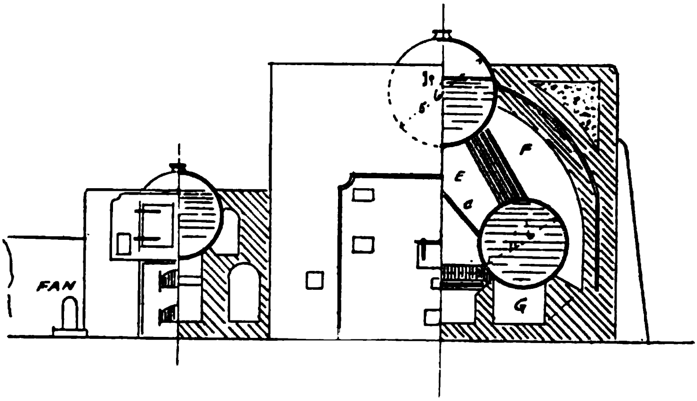

Fig. 62.—Loughborough Destructor—Elevation and Cross-section.

The works are now entirely lit by electricity, the necessary steam being provided by the Destructor.

"Exhaustive tests of ten hours' duration have been made by Messrs. Coltman in the presence of and certified by the Borough Engineer of Loughborough. The refuse was tipped direct from the carts and was entirely unscreened. The following results were obtained:—

Refuse burnt per twenty-four hours	15 tons 14 cwt.
Weight of resultant clinker	3 tons 14 cwt.
Amount of clinker	24 per cent.
Water evaporated (from feed at 36 deg. Fah. raised by multitubular boiler to 150 deg. Fah.) per lb. of refuse burnt	2·02 lb.
Water evaporated from 212 deg. per lb. of refuse burnt	2·38 lb.
Steam pressure	65 lb. per sq. in.

Power available	98-I.H.P.
Temperature in furnace and first flue	2500 deg. Fah. (copper and steel fused)
Temperature in bottom flue at front	970 deg. Fah. average
Temperature in main flue of gases leaving Destructor	590 ,, ,,
Temperature of gases leaving multitubular boiler to chimney	215 ,, ,,
Temperature of feed-water	36 ,, ,,
Temperature of feed-water after multitubular boiler	150 ,, ,,
Water evaporated in tank under bars	6 gallons per hour
Air pressure under bars	1½in. of water
Portion of steam consumed by fan	3 per cent.

The Destructor, buildings, and chimney cost £1400. The Loughborough furnace, consisting of one cell only, disposes of over 80 tons of refuse per week. One man feeds and clinkers for eight hours—the furnace being worked in three shifts. Each man is paid 21s. per week. Repairs and renewals have cost only about £10 since the Destructor was erected in September, 1896, and six new fire-bars have been required since that time.

Manchester.

The area of the city is 12,911 acres, the population 534,300, and the rateable value £2,955,775. In the work of cleansing and of the removal and disposal of the refuse of Manchester, nearly 2000 men, 400 horses, and 500 vans and carts are employed. The cleansing department of the city is the largest in the kingdom, and its payments for the year 1897 amounted to £172,874, whilst the amount received from sales, &c., was £41,080.

A portion of the total collection of refuse is burnt in Destructors, which are distributed at several depôts throughout the city, the greater part, however, being dealt with at Water-street and Holt Town, on opposite sides of the district.

At Water-street, after the fæcal matter and ash have been separated for use at Carrington Moss as manure, the rough refuse, including papers, broken bottles, old boots, tins, and various other rubbish, remains to be consumed in the Destructor furnaces and reduced to a clinker. The oldest of the furnaces now in existence at Water-street were probably the first of the kind ever erected. Twelve modern-type Destructor cells are also in use at this depôt, and steam is maintained in two Galloway boilers by the use of refuse as fuel. This is utilised in driving engines of 300-horse power, which work a number of mortar mills in a space adjacent to the Destructors, and will also be used for lighting the place by electricity.

The clinkers are thrown out of the cells by means of mechanical arrangements in the furnaces, and are broken up and ground into mortar, for which there is a large demand at 4s. per ton. For the year 1895 the mortar made at Water-street sold for £1915, of which £715 was profit. The gross revenue from mortar at all departments was £3764, of which about 33 per cent. was profit.

The following Destructor furnaces are in use in the city:—

Old type of Destructor	14 cells
"Whiley's" patent Destructor...	28 ,,
Ordinary furnaces with Galloway boilers	2 ,,
Ordinary furnaces fitted with movable bars	13 ,,
Total	57 cells

The steam generated by the Galloway boilers is utilised to drive machinery for grinding clinkers from the Destructors into mortar and grit for slippery streets, also for riddling the refuse and converting the liquid fæces into a dry, portable manure.

The labour at the following four Destructors is as follows:—

Destructor.	Description.	Cells.	Approximate amount of refuse burnt per cell per 24 hours.	Cost per ton of burning refuse.
			Tons.	d.
No. 1 (Water St.)	Corporation design, old type	12	6 to 8	6·9
No. 2	Whiley's patent, fitted with automatic movable fire-bars	12	6 to 8	3·47
No. 3	Galloway boilers, fitted with movable bars, hand-worked	2	10	16·8
No. 4	Galloway boilers of ordinary type with fixed bars	2	6 to 8	24·00

From the above it will be seen that the average cost of burning the refuse is about 12·8 pence per ton.

In Destructors Nos. 1 and 2 the men, twelve and six in number respectively, work in two twelve-hour shifts, and receive a rate of pay of 5½d. per hour, working fifty-three hours per week. In cases Nos. 3 and 4 the labour is provided in three alternate shifts of eight hours each, the rate of pay being 28s. per week of forty-eight hours.

Forced draught is not in use at the above. The chimney shaft is 200ft. in height.

The cleansing department of the city of Manchester has to deal yearly with vast quantities of refuse, a large portion of which is due to the prevalence of the pail system and middens.

There are several industries carried on by the department besides the treatment of refuse by fire. These include the manufacture of concentrated manure, and the manufacture of oil and tallow, which form important branches of the Corporation's trading. "During the last ten years it has reclaimed the large barren area of Carrington Moss, and by the application of night-soil manure has made the peat bog one of the most fertile estates in Lancashire. To relieve the congestion of material, the city has now bought the still larger Chat Moss Estate, and on this area of some 3700 acres it is hoped the bulk of the suitable refuse of the city may be used with profit for generations to come. But, beyond this, the Corporation makes a special concentrated manure out of the fæcal matter, and conducts a large trade in this commodity. Out of the fish and animal refuse it makes oil, tallow, and soap, on a commercial basis; the clinkers from the Destructor furnaces are made into mortar, and sold at a fair profit, bringing in a revenue to the city; and the grit necessary for the greasy streets is ground from the clinkers."[1]

Some idea of the magnitude of the work of the cleansing department may be formed from the fact that for the year ending March, 1896, the Committee spent a total of £177,792 in carrying out its duties. For the same year the receipts amounted to £42,695, thus making the net cost £135,097. The net cost of scavenging the streets for the year was £40,421, or 1s. 5·75d. per 1000 square yards of street surface swept.

There are three refuse depôts in different parts of the City, but the bulk of the refuse is dealt with at Water-street and Holt Town. The following are the approximate quantities of material disposed of at these depôts during the year 1896:—

	Water Street. Tons.	Holt Town. Tons.
Dry soil or pail contents and ash-box refuse	84,496	106,568
Night-soil	804	17,611
Fish refuse	714	474
Slaughter-house refuse	3,209	1,692
Market garbage	6,183	—
Street sweepings	37,869	—
Warehouse refuse	4,958	—
	138,233	126,345
Holt Town	126,345	
Refuse sent direct to tips	68,535	
Total	333,113	

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[1] *London*, November 12th, 1896.

This mass of refuse is disposed of in various ways, such as burning in Destructors, manufacturing into concentrated manure, sending to Carrington Moss for manure, boiling down for oil, &c.; the remainder is sent to the tips.

For purposes of collection the city is divided into districts, each having a separate depôt, with a certain number of vans and men allotted to each. In the business of the collection and disposal of the refuse, 1878 men, 12 women, and 416 horses, and about 500 vans and carts are employed. The collecting vans are built to hold twenty-four pails, each in a separate compartment 2ft. in height, closed with folding doors and covered with an arched top. The vans cost about £50 each, are strongly built, on springs, and weigh 38 cwt. when empty and 56 cwt. when loaded.

There is a separate compartment at the rear of the van to receive the contents of the refuse boxes. The excrement receptacle is a circular galvanised steel pail, 17in. in diameter, 13½in. in depth, and 10 gallons in capacity. It costs, with cover, about 12s. For house refuse, the receptacle used is a galvanised iron box, 2ft. in length by 1ft. 6in. broad by 14in. deep, fitted with handles at each. Both pails and refuse boxes are the property of the Corporation, who keep a number of men engaged in making and repairing them. The cost is borne out of the rates—no charge being made to the owner for their use. They are removed once a week, or oftener if necessary, and are covered with a hermetically-sealed iron lid, fitted with an india-rubber ring, which effectually prevents any spilling. The house refuse is collected at the same time, and removed in the special compartment or hopper at the rear of the van.

The carts on the west side of the city convey their loads to the Water street depôt. Here the refuse from the hopper is emptied down a shoot to a rotary riddle; the rough material passes to the furnaces and is burnt, whilst the fine ash which has passed the riddle is used as an absorbent for the fæces in the pails.

The manufacture of concentrated manure, as carried out at Holt Town, is an important industry of the Manchester Corporation. The pail refuse from the collecting vans is tipped into a hopper and revolving riddle, which removes the more solid portion. The liquid is run into tanks, where sulphuric acid is added in sufficient quantity to fix the ammonia in the manure, which is then run into steam-jacketed evaporators, where it remains until properly dried. It is then thoroughly mixed with the fish refuse and material from the slaughter-houses, dried in a similar manner. To complete the process of manufacture a sufficient quanity of finely-ground, pure English bone meal is added to bring up the amount of phosphates to the required standard, and the whole is turned over several times and thoroughly mixed by machinery.

Every part of the refuse appears to be utilised in some form or another, oxide of iron paint being manufactured from the old tins, and disinfecting soap from the fatty or oily matter obtained from the slaughter-house offal, &c.; its removal also being advantageous to the manure. There is a laboratory at the works, under the charge of a competent chemist, who tests the manure to ensure that the guaranteed standard is maintained; this standard provides for from 4½ per cent. to 5½ per cent. of ammonia, 10 per cent. to 12 per cent. of phosphates, about 1 per cent. of sulphate of potash, and about 40 per cent. of organic matter. The moisture is low, and the proportion of oxide of iron is infinitesimal, so that nearly the whole of the manure is available for plant life in a short period. It is supplied in bags of moderate size, made on the works, and, being in a fine condition, can be drilled, or sown broadcast. This manure is sold at £3 per ton, delivered within 100 miles in 4-ton lots, or within 50 miles in 2-ton lots. It has been manufactured for nearly twenty years, and has been sent to Scotland and many English counties, and even to the Channel Islands and Jamaica.

During the year ending March, 1896, 7191 tons of the manure were made, and realised £20,952, and the industry contributed £2802 to lessen the expenses of the depôt.

At the third depôt, in Oldham-road, are the Corporation Workshops, where most of the implements for the Cleansing Department are made, including rubbish vans, railway trucks, carts, harness, street brushes, &c.

Melbourne (Victoria).

A 2-cell Destructor exists in the city of Melbourne constructed after "Cracknell's" patent. This Destructor was in use for thirteen months from May, 1892, and gave satisfaction. It was discontinued during collapse of the boom for economy, and has not since been working. It had to deal with street sweepings, contents of street gullies and catch-pits, and house refuse; also private waste from shops, factories, warehouses, &c., which took the place of fuel, none of which was bought. Each cell was capable of thoroughly burning over 20 tons per twenty-four hours. The cost for labour, with wages at 7s. per day of eight hours, was 1s. 7d. per ton.

Not much surplus steam is produced, and the boilers are special annular boilers, primarily used as a drying passage for the refuse on its passage to the cells. Two "Sturtevant" fans are driven, and enough power remains, if required, to mechanically charge the cells. The chimney is 90ft. in height, and the works cost £4500.

The following particulars of "Cracknell's patent City Refuse Destructor" are from a report[1] to the patentee by Messrs. A. C. Mountain, A. Clayton, and P. J. Nolan, City Surveyors of Melbourne, Richmond, and South Melbourne respectively. These gentlemen state that, "having had special facilities for closely observing the work done during the past six months by the 2-cell Destructor recently erected for the city of Melbourne by Mr. Cracknell, and bearing carefully in mind the very great difference between our ordinary city refuse and that obtained from English cities, we are in a position to arrive at conclusions on this matter with a greater amount of certainty as to facts than can always be secured in similar cases."

The Destructor above referred to is the first of the kind that has yet been erected, but the city of Fitzroy has also decided to erect one. The following is a description of the furnace :—

The Cracknell Destructor consists of a receiving house for the refuse, con structed at a level of 8ft. above the floor of the furnace room.

Adjoining it are two destructor cells, each with a fire grate area of 49 square feet, and fitted with an annular boiler 8ft. 6in. long by 6ft. in diameter, the open inner space of the boiler forming a drying chamber, through which the refuse is passed on its way to the furnace. This arrangement partially dries the refuse and renders it more inflammable.

The cells are so designed that the heat generated by the burning garbage passes under and round the boiler, and thereby produces in it sufficient steam to drive two 10in. Sturtevant's fans, one of which is attached to each cell. The object of this is to both draw off the foul air from the receiving house and the drying chamber, and at the same time deliver it by means of a cast iron pipe under the fire-grate of the furnace, thus creating a very powerful forced draught, which greatly increases the efficiency of the Destructor by raising the temperature of the fire.

At the end of the cell next the boiler a "muffle" is built, with perforated side-wall and arch, which further intensifies the heat and ensures the more thorough combustion of any light matter that might otherwise escape to the chimney.

The flues are brought back over the arched roof of the furnace, so that a large proportion of the dust produced during combustion is arrested in pockets formed in the brickwork, whilst any remaining dust is collected in a chamber at the foot of the chimney stack.

It will thus be seen that the work of cleaning out the dust from the Destructor can be performed with ease whilst the furnaces are in full work, in consequence of the dust receptacles being so accessible. As a matter of fact, it is found that comparatively very little dust is produced, owing to the perfect combustion which is secured.

The experience obtained by the actual working of the Destructor has suggested to the inventor the possibility of still more improving it, particularly with a view to minimising the labour of charging the furnaces.

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[1] Dated 9th July, 1892.

Drawings of an improved furnace[1] fitted with mechanical feed have been submitted for our inspection; these will, in our opinion, largely increase the efficiency of the apparatus and reduce the cost of working.

Briefly described, the modifications consist in the substitution of one large boiler and drying chamber to every *pair* of cells for one boiler, &c., to each *single* cell, as at present; whilst the grate area is enlarged to 81 square feet by lengthening the furnace to 18ft.; a clear space is left under the fire-bars to enable a range of small trucks running on a tram line to be placed so as to catch the ashes, whilst the cells are so designed that, large though they are, every part of fire-grate area can be easily reached by the firemen, who are able to clinker from three sides of the furnace.

The receiving house is enlarged to enable carts to get over the Destructor on either side, and deposit refuse close to two shoots which are provided, connecting with each cell. The object of these shoots is to enable any stuff which does not need preliminary drying to be at once fed on to the furnace, thus reducing the quantity which has to pass through the drying chamber of the boiler.

The wet refuse will be tipped, as at present, on the floor in the centre of the receiving house, but will fall into a hopper or trough leading up to the drying chamber. A specially constructed ram works backward and forward along this hopper, and in doing so thrusts the refuse gradually into this chamber, and thence on to the fire. The ram is worked by hydraulic power, imparted by means of a pump working against a small accumulator, the steam being obtained from the furnace boiler. It is anticipated that a water pressure of about 120 lb. per square inch will be ample for this duty.

An additional improvement is also effected by the use of an independent fan for drawing off the vapours from the drying chamber, the large fan being exclusively devoted to exhausting the foul air from the receiving house.

Destructors have long been used in the chief cities of England for consuming the town refuse, but they have only lately been introduced in Melbourne. Two types have been erected—a 12-cell "Fryer" for the city of South Melbourne, and a "Cracknell"—above described—for the city of Melbourne. As the erection of other Destructors will, sooner or later, become a necessity for the various cities in Victoria, under the requirements of the present Health Act, it becomes an important matter to ascertain which type is the most suitable to the needs of the country.

It will be well here to make a more detailed reference to the kind of refuse which a Destructor in Australia is called upon to treat, the character of the stuff being so different from what obtains in an English city. The published statements of the capabilities of Destructors in England can, therefore, hardly be accepted as an index to their possible efficiency were they introduced here.

For this purpose a comparison between the refuse of this city and that of London may not be out of place, seeing that both cities are capital towns, and represent fairly an average of the material to be treated throughout their respective countries. London is also a water-closet town, and Melbourne (in view of the fact that it is not proposed to treat any night-soil by means of Destructors) may, for the purpose of this inquiry, also be regarded as one.

In London, where coal is universally used as fuel, the house refuse is stored in covered receptacles, which are emptied weekly. This refuse consists of from 70 to 80 per cent. of ashes and cinders, the remainder being chiefly vegetable refuse of a comparatively dry character, broken crockery, &c.; whereas the refuse of Melbourne consists chiefly of vegetable refuse, often of a partly decomposed character and saturated with moisture, together with a large proportion of channel and right-of-way sweepings, which, in the present absence of underground sewerage, are necessarily breeding-beds of disease, and for that reason should undoubtedly be destroyed. When the London refuse is collected, it is first sifted, by which means the ashes are removed, and, under the name of "breeze," are sold chiefly for brick burning. Even after the ashes are taken off, a large proportion of fuel is left behind; and when the residue is freed as far as is practicable from broken glass, crockery, &c., there is left a substance which is readily burnt and is very different from the sodden and heavy refuse to be treated here.

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[1] I understand that, as carried out, the alterations have not been a success; the original type being better.

In the "Fryer" Destructor the refuse is deposited directly into the cell, where it is consumed at a comparatively low temperature. With dry, loose refuse, containing a large proportion of fuel, the combustion was fairly done in England, but still a large amount of vapour was found to escape, to remedy which a cremator was devised by Mr. Chas. Jones, A.M. Inst. C.E., to consume the gases after leaving the furnaces on their way to the chimney shaft. These cremators undoubtedly do a certain amount of good; but in order to effectually decompose the vapours escaping from the furnaces a very much higher temperature is necessary than is usually maintained in them, involving the consumption of a considerable quantity of fuel, estimated by the inventor at the rate of about £18 per Destructor cell in operation per annum; but (as stated by Charles J. Lomax in his work on "The Collection, Treatment, and Disposal of Town Refuse") amounting in the case of the Destructor at Bradford to not less than £88 per annum per cell, with coke and breeze at 8s. and 3s. respectively per ton. Unless the proper temperature is maintained in the cremator a certain amount of steam can be generally seen escaping from the top of the chimney, especially when the refuse is of the description met with in most Australian cities.

The patent Destructor of Mr. Horsfall, of Leeds, is an improvement on the above-described furnace, by introducing a forced draught in the shape of a steam jet under the fire-bars, which increases the temperature of the cell to such an extent that the cremator is only used at the commencement of the work before the furnaces get thoroughly heated. By this means also, and by the use of rocking bars, it is claimed that the capacity of the cell for combustion of refuse is considerably increased, as the following extract from a report on Destructors by Mr. T. H. Yabbicom, A.M. Inst. C.E., will show: "At Birmingham, before the Horsfall blast was applied, the furnaces only destroyed at the rate of 5½ tons per diem, but after the application of the steam jet 8 tons per cell per diem were destroyed."

Yet here again the fact remains that the material operated upon was essentially different in character to what has to be treated in Melbourne, and these performances have to be viewed in connection with that fact.

In designing the "Cracknell" Destructor, the inventor has evidently endeavoured to compensate for absence of fuel in the refuse he has undertaken to deal with, by converting as much as possible of the water contained therein into gas; and by keeping up the temperature with the aid of a strong blast has succeeded, in consequence of the much higher temperature obtained in these furnaces than in those of the "Fryer" type. There can be no doubt that the destruction of the refuse is more effective, the residual clinker is much harder, and no vapours can escape from the chimney when once the furnaces are in ful work.

The practical issue of this question resolves itself into the following points:—

(1) Relative efficiency of Cracknell's Destructor.
(2) Prime cost in construction.
(3) Cost of working.

Efficiency of the Cracknell Destructor.—The exceptional test to which the Cracknell Destructor at Melbourne was subjected to, demonstrated its efficiency under very trying conditions; whilst its subsequent working, under the normal duty required from a Destructor dealing with average Australian city refuse, has shown that this efficiency is combined with fair economy in working, capable of being in the future still more improved.

For a period of between three and four months this Destructor was worked under exceptionally stringent limitations as to the class of refuse which was allowed to be treated by it. Only that collected by the municipal cleansing contractors' carts while carrying out the combined duty of sweeping street channels, cleansing rights-of-way, and emptying dust-boxes, was put through the furnaces; all trade refuse and rubbish in excess of the maximum quantity of 3 cubic feet, which the contractors are obliged to remove from every tenement on each visit, being rigidly excluded. This ensured, probably, a more severe and searching test than has been applied to a Destructor, seeing that the stuff treated consisted largely of non-inflammable matter, whilst in the majority of cases the combustible portion of the refuse was saturated from admixture with wet mud and slush.

Without the aid of some fuel, stuff of that character would under hardly any circumstances be kept in continuous ignition. Under this test Cracknell's Destructor thoroughly treated an average of 14½ tons of stuff per cell per day with an average expenditure of £1 0s. 6½d. for fuel. All the refuse was carefully weighed; indeed, in connection with these experimental trials no less than 3579 loads of various kinds of city refuse were passed over the weighbridge, affording valuable data on which to estimate the amount of work subsequently performed.

Since the Destructor has been at regular work for the City Council of Melbourne (*i.e.*, from the 12th of May, 1892), the average per cell for a period of fifty days has increased to 22 tons per diem, *and no fuel whatever* has been employed. This has been effected by the mixture of the previously described city refuse with waste stuff and private refuse, intended to be buried or destroyed, which acts as a substitute for fuel by adding to the inflammability of the mass.

The heat thus generated enables a steady pressure of from 70 lb. to 80 lb. per square inch to be maintained in the boilers, the steam from which latter works the vertical engine which drives the fans used to abstract the foul air from the receiving house. All nuisance is thereby avoided.

Smoke from the chimney is hardly ever seen; when apparent, it is of the lightest character, and not at all of an objectionable nature; whilst the amount of dust created is small, and is removed from the pockets over furnaces and the dust chamber at foot of chimney once a fortnight, the time occupied in this work being about ten minutes.

First cost of construction.—The contract entered into by Mr. Cracknell with the City of Fitzroy for a 2-cell Destructor affords a guarantee that it will consume at least an equal quantity of refuse to what can be treated by eight of Fryer's cells, provided the material be of a similar character. The entire work will be built in the Colony, under the supervision and to the approval of the Surveyor of that city, and the cost will be about equal to that estimated for an 8-cell "Fryer."

The actual cost of a "Horsfall" Destructor can only be guessed at, as the representatives of that furnace have not given a price for the complete installation of their Destructor in Australia (like Fryer's, they only submit the f.o.b. cost of ironwork in England). To treat the above amount a six-cell "Horsfall" would be needed, the cost of which would, in our opinion, be about equal to that of Cracknell's.

It may therefore practically be assumed that there is but little difference between these three types in the matter of first cost; indeed, a little alteration of the royalties charged could raise or lower the price of either.

As the "Cracknell" Destructor, already described, is now treating from 40 tons to 44 tons daily, and as the one to be erected for Fitzroy will contain all the subsequent improvements (in the shape of mechanical feed, side shoots, &c.) previously alluded to, there is a fair prospect that the newer furnaces will be able to destroy more than the stipulated amount.

As regards "Fryer's," from observation of what has been done in South Melbourne we are of opinion that this furnace is not likely to exceed the capacity claimed for it, viz., 6 tons per cell, or 48 tons for eight cells, in twenty-four hours.

"Horsfall's" Destructor claims to treat 9 tons per cell, but has not yet been tried with Australian refuse. There is no reason to believe that this estimate, based on English city refuse, will be increased in Australia, for reasons already given. There can be no doubt, however, that the application of the steam jet at the closed ashpit has enabled this type of furnace to obtain more perfect combustion than Fryer's gives, and produces a temperature more nearly approaching the "white heat" which is found in the muffle of the Cracknell Destructor.

The actual temperature recorded by the pyrometer in Cracknell's muffle is 1450 deg., 1650 deg. on the floor of muffle, 1800 deg. in furnace, and 875 deg. in flue over furnace.

Cost of working.—The comparative cost of working the two types of Destructors erected here has been furnished by the respective Surveyors as follows:—

Fryer's (South Melbourne)...	2s. 6¾d. per ton,
Cracknell's (Melbourne)	1s. 7d. per ton,

showing a considerable saving in favour of the latter. This rate is higher than is generally ruling in English towns; but when the difference of the cost and hours of labour there and here is considered, as well as the different character of the material heated, the result is very satisfactory.

Summary.—The above remarks are the outcome of considerable study of the question of city refuse destruction, derived from knowledge gained from the information published on the subject, and also in a practical manner from experience obtained from the working of the only Destructor yet erected in Australia.

In dealing with this matter we recognise its importance to every city in this country; and we have endeavoured, without bias or prejudice, to express our judgment on the merits of this invention, based solely upon facts within our own knowledge, or on information obtained from reliable authority.

Briefly stated, we are of opinion that Cracknell's Destructor is not more expensive to erect than are rival furnaces of corresponding capacity; that it is cheaper in cost of working; and that the destruction of refuse is more thoroughly accomplished by it than by any Destructor yet introduced. The nuisance created by large masses of garbage is minimised by the arrangement of the receiving house, which also affords sufficient storage space under cover to accommodate enough refuse to keep the furnaces continually running during the twenty-four hours.

The work of dust removal is also accomplished speedily and without inconvenience, whilst no nuisance from smoke arises in the chimney.

In conclusion, we desire to express our decided opinion that Mr. Cracknell has made a distinct advance on anything that has yet been done in the construction of Destructors for treating refuse as found in Australian cities.

Mr. A. C. Mountain, City Surveyor, Melbourne, reporting to his Public Works Committee in June, 1892, upon the work of the Cracknell Destructor, observed that the work done to that time embraced 500 working hours between May 12th and June 4th, during which time the material treated was a fair sample of the general city refuse, obtained from cleansing of channels, rights-of-way, and emptying dust-boxes, &c., as collected by the scavenging carts. This was destroyed with the assistance of private refuse sent chiefly from factories, warehouses, &c., which served as a substitute for ordinary fuel, which latter was not used at all. There was a gradual increase in the work done, beginning with the broken week, when 39½ tons were put through per day, and finishing last week when nearly 42¾ tons were burnt, or at the rate of 21⅜ tons per cell during each twenty-four hours. The average per cell during the past three weeks has been about 20¾ tons per cell per day of twenty-four hours. The cost of labour was 1s. 7d. per ton of stuff burnt, which, allowing for the difference of rate of wages in Victoria and in England, compares favourably with English results. If mechanical contrivances were devised to charge the furnaces, which were fed by manual labour, Mr. Mountain believes that the expense of working would be reduced.

South Melbourne.

At South Melbourne is a 12-cell "Fryer" Destructor, the particulars of the working of which for the year ending 2nd January, 1892, are as follows:—

The population of the City is about 40,000, and six of the cells only are required to meet present needs. The twelve cells, it is considered, are adequate for a population of 80,000. The total cost of erecting the Destructor was £7464 18s. 5d.

House refuse, dead animals (exclusive of cows and horses), and a little trade refuse are dealt with. The total quantity of refuse amounted to 9512 loads, or 8561 tons, of which 112 loads were mussels and 103 loads non-inflammable trade refuse. An average load weighed 18 cwt. The cost of working was 2s. 6¾d. per ton, or 2s. 3⅜d. per average load.

During the year the fuel used was as follows:—

		£	s.	d.
In Destructor—72 tons 16 cwt. of coal, at 18s. 6d. per ton	=	67	7	4
In Cremator—68 tons 12 cwt. of coke, at 18s. 6d. ,,	=	63	9	7
		£130	16	11

Eight men were employed during the year, and the amount of wages paid to them was £980 18s. 2d. The only repairs chargeable to wear and tear are repairs to castings, which cost £1 18s. 5d.

In consequence of sinkages of foundations caused by a great flood, repairs had to be effected to the main flue which cost £31 9s. 2d., but this is not chargeable to wear and tear. There is no nuisance arising from either smoke or dust.

Nelson.

The area of the district is 3185 acres, the population 33,000, and the rateable value £106,000. At Nelson there is an old 3-cell "Nelson" Destructor—the only one of its kind—it was erected by Messrs. Richmond and Co., Burnley. The Borough Surveyor says, "As it is about the most costly in work of any Destructor ever erected, we are about to abandon it and erect a new Beaman and Deas' furnace." The cost of burning the refuse with the "Nelson" Destructor, including fuel, amounted to about 5s. per ton, and the cost of cremating the fumes about 3s. per ton, the total cost thus being from eight to ten times the amount it should be if a modern-type Destructor were used. It is proposed to lay down two Beaman and Deas' cells, with 120-horse power boilers, and a chimney shaft 180ft. high. The new furnaces, it is anticipated, will consume 20 tons of ashpit refuse per cell per twenty-four hours.

Newcastle.

The area of the city is 5371 acres, the population 212,223, and the rateable value £1,014,610. The town refuse is dealt with in several ways. Part is sent to sea and part burned in Destructors, but nearly one-half is deposited on fields and tips within the neighbourhood, and some is sold to farmers.

In 1885 six Destructor cells of the "Fryer" type were erected, and in 1891 six additional cells were laid down for the Corporation by Messrs. Goddard, Massey, and Warner. The shaft is 150ft. in height, and the works cost about £7000. Six tons of refuse per cell per twenty-four hours are at present dealt with at a cost of 8½d. per ton for labour.

Some interesting details of the burning of town refuse in Newcastle are given by Mr. W. Geo. Laws, C.E., the City Engineer, in a paper read before the Health Congress, London, August, 1891, in which he gives the practical results of five years' (1886 to 1891) burning in the six cells first erected. He says :—

> The authorities of Newcastle-upon-Tyne in 1885 determined to make a trial of refuse burning, and, having secured a suitable site on their own property, put down the plant for a Destructor of twelve cells. Wishing to feel their way, they erected at first six only of these cells, which were completed in June, 1886, and have been steadily burning night and day ever since.

The capital cost of erection was £5060, which included a chimney shaft large enough for twelve cells, and also roads, tram-lines, and other works necessary for the larger establishment, so that the increase to twelve cells now just completed (1891) has cost in all £7000.

The results now given are of the working of the six cells only, and they have been debited with the full capital at first expended—viz., £5060. The interest on this has been taken at 4 per cent., being ½ per cent. more than the Corporation of Newcastle pays on its stock.

No charge for redemption has been taken into account, it being considered that where the plant was fully kept up by repairs and renewals, a fairer estimate of the actual cost would be arrived at by taking interest only on capital, and charging repairs and renewals as they occurred.

The site on which the works stand had been let by the Corporation for market gardens, at £5 per acre, and when handed over to the Sanitary Committee, the rent was raised to £10 per acre, or £25 for the 2½ acres occupied. Rates and taxes are charged as paid, the site being within the boundaries of another Authority.

A careful and regular account has been kept of all the material brought to the Destructor. A charge of 1s. per ton is made to all private persons, tradesmen, and others, who send refuse for burning, and also when diseased meat or food stuffs condemned as unfit for use are dealt with. Clinker and ashes are sold to contractors and others at what prices they will fetch, and when used by the Corporation themselves, are charged at the same prices as paid by the public. These various receipts are treated as credit items, and deducted from the total cost of burning.

The result of the whole five years work is as follows:—We have burnt 61,120 tons of material at a net cost, including all expenses, of £3097, making the cost of burning just over 1s. per ton, or more exactly 12·16d.

This cost may be divided thus:—

	Per cent.	Per ton. d.
Interest, rent, rates, taxes, &c	37·6	4·56
Repairs and renewals	8·8	1·10
Labour	53·6	6·50
	100·0	12·16

With respect to this last item of labour, there is a somewhat noteworthy fact to record. For the first three years and a-half the work was done by two shifts of twelve hours each. At the end of 1889 there was considerable agitation in the labour market, and the gas stokers got a very material reduction of hours and increase of pay.

The Destructor men claimed a similar change, and the shifts were reduced to eight hours each, that is, three shifts are now employed, working eight hours, and resting sixteen hours. The wages, by agreement with the men, remained the same per shift, so that the cost of labour was raised just 50 per cent. Naturally it was expected that the cost of burning would rise proportionally, that is, about 25 per cent., as labour formed about 50 per cent. of the work.

On working out the results, however, at the end of 1890—1, and up to date, the cost of burning, which, up to the end of 1889, was 12·3d. per ton, has actually fallen to 11·9d., or nearly ½d. per ton, while labour alone, for the first three and a-half years was 6·9d., and for the last eighteen months 7·7d. per ton. This is an interesting and significant fact, and the writer cannot but call attention to it as throwing a light on the labour question, which must be specially interesting to engineers. Here is a case where with identically the same plant and machinery, a lessening of the hours of work by one-third, viz., from twelve to eight, while increasing the total wage paid by 50 per cent., actually so far increased the output as to slightly reduce the cost per ton.

It appears that, with three shifts of eight hours each, the burning capacity of each Destructor cell is slightly over 2500 tons per annum, or 8 tons per day of twenty-four hours. When it was attempted to increase this output, it was found that the stuff was not so well burnt, and the residue more bulky. As nearly as can be estimated, the total residue is from 25 to 30 per cent. of the material burnt. It consists of a hard clinker, which has been found very useful for many purposes, and of sound dry ashes, which readily sell at 6d. per ton up to the full demand of them; but so far the output far exceeds the demand, and the unused part is tipped into an old quarry, where it is gradually forming useful land, that will one day come into the market as building land. The clinker has been much used for making the concrete bed in which the sanitary pipe sewers of Newcastle have been laid for the last nine years.

The particulars of cost of five years' refuse burning are:—

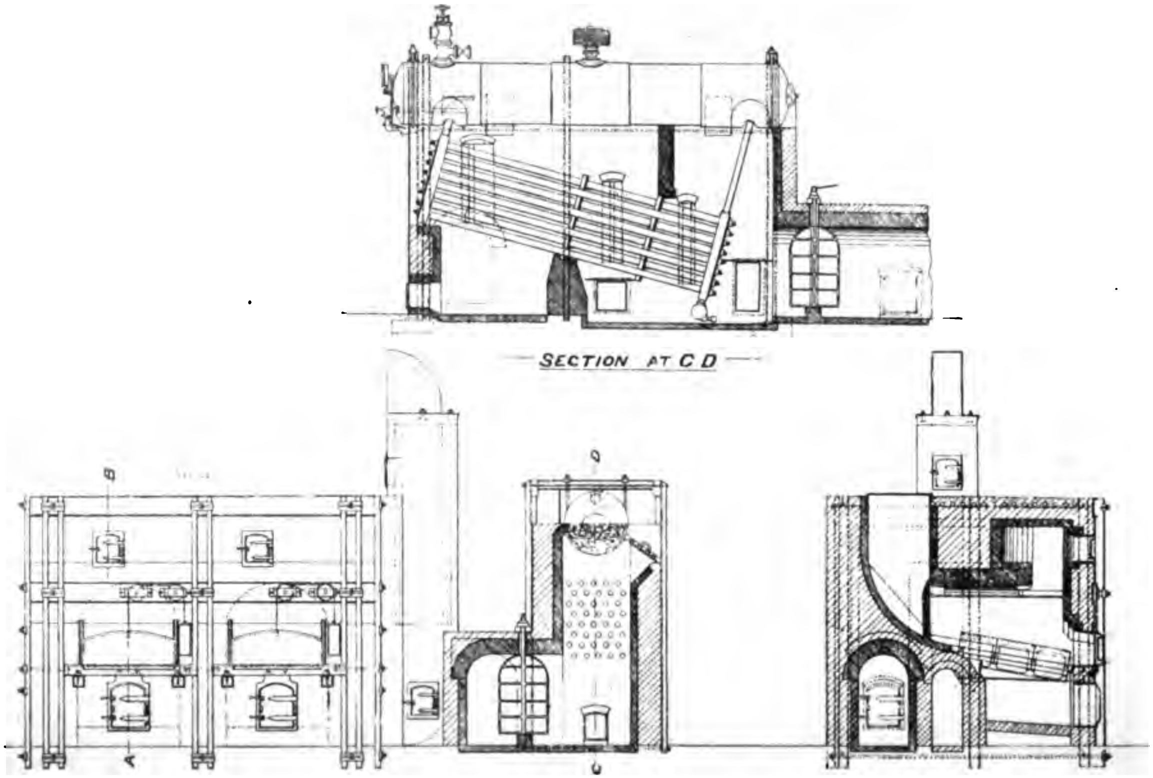
	£	s.	d.
Total cost of burning 61,123 tons of refuse, including labour, repairs and renewals, rent, rates, and interest	3383	6	2
Deduct receipts for burning private refuse, and for sales of clinkers and ashes	286	12	10
Net cost	£3096	13	4

£3096 13s. 4d. ÷ 61,123 tons = 12·16d. per ton.

The cost may be divided as follows:—

	£	s.	d.	Percentage.	Cost per ton net in pence.
Rent, &c.	1272	10	0	37·61	4·56
Labour	1813	12	0	53·60	6·51
Repairs	297	4	2	8·79	1·09
					12·16

As regards the work of the Byker Destructor for the year ending March, 1897, it appears from the Borough Engineer's annual report that this Destructor continues to do its work well and cheaply, the cost of burning having been now reduced to 8½d. per ton. 20,016 tons were burnt at a net cost of £715 7s. 9d., after reckoning all outgoings and receipts from various sources. This works out to a fraction over 8½d. per ton, as against 8⅝d. last year, and if the account be further debited with interest at 4 per cent. (which is ample, as all



SECTION AT C D

ELEVATION OF FURNACES

SECTION THRO BOILER AND FLUE

SECTION AT A.B

TWO-CELL HORSFALL DESTRUCTOR AT NORWICH.

[Face page 307

repairs are already included) and rent of site, the cost is exactly 1s. per ton.

This compares very favourably with the cost of sending to sea from Mitford-street, where 22,324 tons have been dealt with, at a cost of £1700, or a price of 1s. 6½d. per ton, and here again, adding interest at 4 per cent., the gross cost is 1s. 7d. per ton.

Against this, however, is to be set the saving in cartage between leading the stuff uphill to Byker and downhill to Mitford-street, which cannot be less than 9d. to 1s. per ton.

The greatest economy would, of course, be got by having the Destructors at the riverside, and so saving both in cost of leading and cost of dealing with the material. Unfortunately, the opposition, on sentimental grounds, is too strong, though there would be an actual saving to the rates of about £2000 per annum, or ½d. in the pound.

Norwich.

The area of the district is 7587 acres, the population 100,964, and the rateable value £344,356. The town refuse is removed under contract with the neighbouring farmers, but quite recently a 2-cell Horsfall Destructor has been erected. The cells were finished in January, 1898. The surplus heat is to generate steam in an 80-horse power Babcock and Wilcox boiler for the purpose of driving air-compressing engines for sewage pumping on the Shone system. The chimney shaft is 100ft. high. The cost of the installation will be from £2500 to £3000, but the circumstances are exceptional, there being an old building adapted to contain furnaces and boiler and an existing chimney. Also, no room existed for the usual inclined roadway, and an overhead traveller, trucks with opening bottoms, and a low-level railway for same below the tipping beam, have been provided. Additional cells up to six can be added at little more than the bare cost of the cells.

Nottingham.

The area of the city is 10,935 acres, the population 233,000, and the rateable value £901,826. A 5-cell "Fryer" Destructor was erected by Messrs. Manlove, Alliott, and Co., in 1882, at a cost, including electric light installation, of about £6000. From 30 to 40 tons of refuse per day are dealt with, the cells thus consuming about seven tons per day per cell. The rough dust is in part screened for use under boiler. Four cells were fitted with Horsfall's patent forced-draught apparatus in 1893. The chimney is 160ft. in height, and no cremator is used. Waste heat is utilised for elevator to Destructor, for steam pumps and electric light installation. The cost of collection of the refuse varies from 1s. 10¼d. to 3s. 4d. per ton. About 20 per cent. of clinker is produced, but is of no value. Ten men are employed upon each shift, and they work fifty-three hours per week; the rate of wages for firemen, trimmers, and sorters is 5d. per hour. The wages of ganger is 27s. 6d. per week.

Oldham.

The area of the district is 4730 acres, the population 146,000, and the rateable value £646,918. There is a 10-cell Horsfall Destructor situated near the centre of the town, on the northerly side of the railway, between Clegg-street and Mumps stations. Six of the cells were erected in 1890, and in 1895 these were adapted to the Horsfall improved system, and four additional cells also then added.

The refuse dealt with is derived from open ashpits, and also includes market garbage, offal, &c. Eight tons per cell per day are burned, at a cost of 9¾d. per ton for labour. Good results are obtained in the production of steam from the heat of the Destructor, and surplus steam is passed to the borough Electric Light Works, immediately adjoining, as a supplementary power. It is also used in the Corporation workshops for driving mortar mills and for supplying the steam blast. Now that an additional boiler has been added, 20-horse power are developed continuously per cell. There are two steel Lancashire boilers, each 30ft. long by 8ft. diameter, which work at a pressure of 140 lb. per square inch; the boilers were tested to 210 lb. per square inch. The chimney shaft is 120ft. high, 5ft. internal diameter, and is so built that it may be raised to 180ft. if desired without increasing the base. The cost of the works, exclusive of site, was £4527. There is an economiser consisting of 96 tubes connected with a new Cameron's feed pump, delivering a cold feed to the economiser, and from which it passes hot to the boilers.

There is a steam jet forced draught, which is said to make a great noise; but in the cells last erected the draught is made to enter underneath the fire-grate from a chamber behind the cells—an arrangement by which it is found the noise and nuisance experienced where the draught enters from the front is obviated.

The area of the furnace grate is 27½ square feet per cell. The furnaces are fed by a shovel through a feeding door at the back of the furnace, which method is considered to distribute the refuse over the furnace more evenly and allow it to burn more freely than the plan of pushing and raking it down through a feeding hopper on the top of the furnace.

The fronts of the ashpits are closed, and steam air-blast is applied under the fire-bars, which creates a greater heat in the furnaces, and a greater consumption of refuse results.

The flue leading to the chimney, instead of being over the back of the furnaces, is at the side, near the front or clinkering door, and thus the fumes from the furnace have to pass over the hottest part of the fire before entering the main flue, instead of passing from the fire over the refuse, which is drying or stewing on the dead hearth and giving off offensive fumes.

There is no demand for the clinker and fine ash, except what is converted into mortar; this is sold at 5s. per ton. The remainder of the clinker is either used for road-making by the Corporation or tipped to waste.

Twelve men, in three shifts, at 30s. per week, work the Destructor. Although the Destructor is near the centre of the town, no complaints of nuisance have been received.

Oswestry.

The area of the district is 1888 acres, the population 10,000, and the rateable value £44,086. The question of the provision of Refuse Destructors has recently been under consideration, but the Corporation find the cost of them too high for a small town, and the cost of working very expensive. It is therefore proposed to screen the refuse as it is delivered at the depôt, and to use the fine dust for mixing with the manure, for which there is a good sale. The cinders and waste are to be burnt in a special boiler.

Paris.

Refuse Destruction in Paris.[1]—In 1893 the Municipal Council authorised a special Commission to visit England, to obtain full particulars of the systems of refuse destruction by fire in use in this country. The information obtained by this Commission being highly satisfactory, the Municipal Council, in 1894, voted the sum of 23,500 francs for the establishment of a trial Refuse Destructor. The work was begun on October 22nd, 1894, and finished on January 10th, 1895.

Description of Trial Furnace.—The Destructor has been erected at the Municipal Wood-paving Works at Javel. It stands beneath a shed which is open on two sides, and is connected with a generator situated in an adjoining closed hall. The type of furnace is, with some

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[1] From Report (14th March, 1896) of C. Petsche, Engineer of Roads and Bridges, Paris

1 millimetre = ·03937 English inches.
1 metre = 39·37079 „
1 sq. metre = 10·764 square feet.
1 cubic metre = 35·3165 cubic feet.
1 litre = ·035316 „
1 kilogramme = 2·2046 lb,

modifications, that in use at Leeds (Fryer's Destructor). To increase the capacity, however, the width of the cell has been increased to 2 m. (Fryer's 1·52 m.). The grate, inclined at an angle of 23 deg., and consisting of stationary iron bars, 80 mm. by 9 mm., with spaces of 9 mm. (·35in.), has an area of 3 square metres (32·2 square feet). The drying hearth is a continuation of the grate, but its upper end is carried up with a steeper slope. It is 1·80 m. long, and has an area of 3·60 square metres. The reverberatory arch is 1·04 m. high above the grate.

The fumes arising from the drying refuse mingle with the products of combustion, and, after passing over the hottest part of the fire and undergoing combustion, escape by two lateral flues (section 1 m. by 0·30 m.) which wind around the furnace, maintaining its heat, and open into a dust chamber placed at the back of the cell, 2 metres high, with section 9·00 square metres. Here the fine ashes which have been carried off by the gases are deposited, while the gases may be either carried directly to the chimney, or may be utilised to heat the adjoining generator. This generator, of the single-boiler type, has 20 square metres of heating surface. The iron chimney, which is 1 metre in diameter and 31 metres high, was not built specially for the Destructor, having been already in use at the works.

The refuse is raised to a platform over the furnace by means of a lift of 0·300 cubic metre capacity, worked by the transmission of power from the factory. 600 kilos. per hour are raised by this means.

The charging is effected by means of a hopper of 0·450 cubic metre capacity (200 to 250 kilos. capacity), provided with two doors. To prevent the escape of fumes the upper door is shut as soon as the hopper has been charged ; when the furnace requires feeding, the lower door is opened, its motion being controlled by a lever and balance weights. Thrown on to the drying hearth, the refuse, when sufficiently dried, is drawn down upon the fire by the stoker, who for this purpose opens one or other of the two furnace doors. These are of the sliding type, with balance weights. The clinkering doors have double leaves.

Two Körting steam jets have been introduced to assure a good forced draught. They are capable, theoretically, of distributing 400 litres of air per second at an expenditure of 40 kilos. of steam per hour. The air is distributed by four pipes opening under the grate, each having a section of 2·17 square decimetres. The furnace is built of ordinary Fresne bricks, riveted together by solid metal bars; all the parts exposed to the fire are of brick and *pièces refractaires de la Folleville.* This furnace has been at work day and night from January 15th to August 19th, 1895.

It was discovered during this experimental period that the temperatures obtained were not sufficiently high, and the following modifications in the construction of the furnace have been effected:—(1) The drying hearth of masonry has been replaced by one of cast iron. (2) A heat recuperator, consisting of six iron pipes, 0·20 metre diameter, has been erected in the main flue; the clinkering doors being hermetically sealed, the supplying of air is effected at the back of the cell, and this air, heated by its passage through the recuperator, is discharged under the grate. The six mouths of the recuperator can be shut off separately by dampers, so that the air can be supplied in various quantities. (3) The flue openings into the cell have been reduced by half. (4) The addition of cast iron plates to cover the drying hearth enables the latter to be lengthened, taking off from the length of the grate. It has been found, however, that the most satisfactory results are obtained when the hearth and grate are of their original size. The furnace, with these modifications, recommenced work on September 30th, and was kept going until December 29th.

Nature of Refuse Consumed.—The experiments with the trial Destructor during 1895 were carried out with refuse taken from the various quarters of Paris—the rich quarters, the *bourgeois*, the slums, and the markets. The average weight was 527 kilos. per cubic metre for the entire year; 617 kilos. during the cold season (December 1st to March 31st), and 497 kilos. during the warm season (April 1st to November 30th). The average weight in the different quarters of the town varied very little; but the refuse from the markets was considerably lighter—450 kilos. Before burning the refuse, such material as broken bottles, saucepans, stones, &c., was picked out. This material is not worth much; on 306 cartloads there was a profit of 24·75f. A ton of refuse yields, at the outside, broken bottles, &c., to the value of 0·045f.! It is an absolute delusion to expect the slightest profit from this source. A certain quantity of the refuse was sifted previous to cremation, an average of 32 per cent. of ashes, earths, &c., being obtained by this means—40 to 50 per cent. in winter, 15 to 20 per cent. in summer.

Combustion of Refuse.—The refuse burns without the addition of any combustible. There is no marked difference between the combustibleness of the refuse from the different quarters, but the market refuse burns less readily. Left to itself, the fire remains alight from eighteen to twenty-four hours. From the cold to the hot season the quantity of refuse consumed per twenty-four hours increased 25 per cent. in weight and 50 per cent. in bulk. A slight addition of coal (5 to 10 per cent.) and the use of the forced steam draught made no appreciable difference to the capacity of the cell. The primitive type of furnace, analogous to the Leeds Destructor, consumed, on an average

5400 kilos. in twenty-four hours. The addition of the recuperator resulted in the consumption of 7100 kilos. in twenty-four hours. On Sundays and other holidays, when the dampers were closed and the fire left to itself, the cell consumed nearly 2000 kilos. in twenty-four hours. In the case of sifted refuse, about 8000 kilos. were consumed by the primitive type of cell and 12,000 kilos. by the modified type.

Residuals.—The residues for the year amounted on an average to—

37 per cent. in weight (29 per cent. clinker, 8 per cent. ashes), and
22·4 in volume (17·8 per cent. clinker, 4·6 per cent. ashes).

From the cold to the hot season the proportion varied from—

49 per cent. to 32 per cent. in weight.
34 „ 19 „ in bulk.

The proportions vary little in the different quarters, but in summer the residues from market refuse fall to 18 per cent. in weight and 9 per cent. in bulk. Analysis of ashes, per 1000 kilos.:—

	Kilos.
Azote	4·4
Phosphoric acid	7·2
Potash	1·95
Lime	73·4

These have a theoretical value of 6·90f. per 1000 kilos. Analysis of ashes, &c., per 1000 kilos., obtained by sifting refuse previous to cremation:—

	Kilos.
Azote	5·8
Phosphoric acid	5·5
Potash	1·8
Lime	57·5

Theoretical value, 11·50f. per ton.

Temperatures.—The temperatures taken in the arch of the cell give an average of 450 deg. Centigrade in the primitive furnace, and 550 deg. in the modified furnace. The minimum was 190 deg., the maximum 775 deg. The recuperator supplied hot air at 300 deg. The temperature at the mouth of the chimney showed a fairly steady temperature of 200 deg. The generator connected with the Destructor was found to be practically useless for industrial purposes. The 514,000 kilos. of refuse consumed from January 15th to April 30th only produced 27,000 kilos. of steam at a pressure of 3 kilos., *i.e.*, scarcely 52 kilos. per ton. The pressure was with difficulty maintained at 3 kilos. The generator supplied the steam for the forced draught during half the trial period. In the case of the modified Destructor, the production of steam in the generator was practically nil, the pressure being only 1 kilo. These results contrast unfavourably with those obtained in

England. This is presumably owing to the fact that English refuse is much richer in combustible matter. The authorities have come to the conclusion that Parisian refuse, although it can be consumed without the addition of any combustible, cannot be utilised for any industrial production of steam.

Fumes and Odours.—It has been satisfactorily proved that the Destructor does not create a nuisance. At times, when the temperature was low, and the wind drove the smoke downwards, a slight smell of burning was noticeable at a distance of about 600 metres, but no trace of any infectious odour could be discovered. A careful analysis of the fumes, conducted in the laboratory and under the supervision of M. le Chatelier, chief mining engineer, revealed a proportion of 2·5 to 6·5 per cent. of carbonic acid, which indicates an excess of air. No appreciable trace of ammoniacal vapours was discovered, and the fumes appear perfectly harmless to the public health.

Expenses.—The cost of constructing the trial installation amounted to 31,605f. (including cost of chimney and sheds which were already in existence). It is estimated that the cost of constructing a rank of 12 cells, placed back to back, including foundations, would be 300,000f., allowing a sufficient margin for unforeseen expenses. It is difficult to calculate the probable cost of working such a Destructor from the experiments at Javel, which were carried on under unusual circumstances. It has been roughly estimated, however, that, allowing a staff of three workmen for every three cells, the cost of destruction would amount to 2·50f. per ton of refuse. The carriage of the material to be destroyed and of the residuals would bring this cost up to 5·50f., and the amortisement of the capital would increase the sum to 6·70f. per ton. The sifting of the refuse previous to its cremation, the sale of the siftings, and the increased capacity of the cells resulting from the process, would considerably lower the cost of destruction. It is estimated that, including amortisement, the expense would come to about 3·60f. per ton. With the present arrangements for removing the refuse, the cost amounts to 3·80f. per ton on an average. In certain wards, however, these expenses are much heavier, amounting to as much as 4·50f. to 5f. per ton; and here the system of cremation would be a distinct advantage from a pecuniary point of view.

Penang.

The Municipality of Penang has a population of over 100,000, producing annually about 50,000 loads (of 1½ cubic yards each) of refuse.

In regard to the burning of the refuse, nothing beyond the purchase of a site for the erection of a Destructor has yet been decided; but the Municipal Engineer, Mr. R. Peirce, visited England during 1898 for the purpose of inspecting various types of furnaces, with a view to the early erection of a suitable Destructor.

Plymouth.

The area of the district is 2460 acres, the population about 100,000, and the rateable value £400,000. The erection of a Refuse Destructor is under consideration, but the details are not yet available.

Poplar.

The area of the district is 2333 acres, the population 169,267, and the rateable value £742,294. In March, 1898, a Dust Destructor, consisting of fourteen cells, erected by Messrs. Goddard, Massey, and Warner, for the Poplar District Board of Works on land in Glaucus-street, Bromley, at a total cost of about £11,000, was opened by Mr. Mark Dalton, J.P., chairman of the District Board of Works.

For years past the Poplar authorities viewed with some alarm the increasing difficulties of finding shoots for house refuse.[1] Experience has proved the danger to health of dumping it down on any vacant space, to be built over at no distant date, with all sorts of diseases following from the exhalations of the reeking mass beneath, not to speak of the disgusting spectacle of women standing almost waist deep amongst the rubbish engaged in sorting it. Barging it away, which is an increasing expense, would only obviate some of the evils, and after much deliberation it was determined to erect a Destructor. It is now four years ago that the Board acquired the premises at Glaucus-street, at a cost of £3500. The site had been originally in the occupation of a firm of animal charcoal burners, and traces of the business were in evidence when the soil was disturbed. For a considerable depth the ground was found to be saturated with feculent matter, which gave off an almost unbearable stench, and placed it out of question for the site to be used for few other purposes than that to which it will in future be devoted. The premises, in point of situation, are excellently adapted for the purpose to which they are devoted, as in addition to being nearly central in the northern part of the district, and therefore saving time in the carts conveying the dust having to traverse very long distances, there is extensive wharfage offering every facility for conveying away the residuum from the Destructors, should the Board not take steps to utilise it.

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[1] The *East End News*, September 4th, 1897.

The fourteen cells are of Warner's improved patent "Perfectus" type, and are calculated to be capable of dealing with eight tons of house and trade refuse per cell per day. The surplus heat generates steam in a 50-horse power boiler, which is utilised in driving fans for forced draught, clinker, and mortar mills, &c. The installation is not connected with any electric lighting scheme. The shaft, which is about 150ft. in height, was already upon the site. The cost of the works, exclusive of the shaft and site, was £7141.

Preston.

The area of the district is 4089 acres, the population 113,864, and the rateable value £363,617. There are two Refuse Destructors, together consisting of 28 cells, 18 of which are in regular use. The furnaces were erected by Messrs. Manlove, Alliott, and Co., and deal with ashpit and household refuse and garbage at the rate of six tons per cell per twenty-four hours, at a cost for labour of 10d. per ton. The waste heat drives a small engine of 8-horse power.

One chimney is 180ft. in height, the other 250ft.

Reading.

The area of the district is 5878 acres, the population 67,000, and the rateable value £312,921. There is no Refuse Destructor proper at Reading; but in December, 1893, Mr. A. E. Collins, A.M. Inst. C.E., who was then Borough Engineer of Reading, made experimental trials to show whether domestic refuse could be profitably burnt in the furnaces of the three Lancashire boilers supplying the pumping engines at the sewage pumping station on the banks of the Kennet, at Blake's Lock. Mr. Collins gave the following particulars in a paper[1] read at a Municipal Engineers' meeting at Reading in April, 1894. He said:—

> Temporary forced blast fittings were made at the pumping station and fitted to the boiler furnaces. During the past three months (*i.e.*, January to March, 1894) the engines have been driven by steam raised from the combustion of unprepared house refuse only. The forced blast apparatus is of the simplest description. It consists of a sheet of iron fitted to each ashpit front, two holes of a diameter of 5in. are cut in each plate, and two sheet iron cones are fitted to these holes; they have a length of 15in., a diameter at the smaller end, which points under the grate and is provided with louvres to deflect a part of the blast up under the front ends of grates, of 4½in., and a diameter at the larger end of 6½in.; a ⅛in. steam jet, controlled by a valve, plays through the centre of each cone.
>
> The chimney is 140ft. high above the grates, by 3ft. square internally.

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[1] "Proceedings" of the Association of Municipal and County Engineers.

The amount of refuse consumed averages about 18 tons per day of twenty-four hours.

The author has not made any tests to discover the rate of evaporation; he thinks that about 1½ lb. of water are evaporated per 1 lb. of refuse burnt. The furnaces are fired and cleaned by hand, they are fitted with furnace bars supplied by Messrs. Clark, of Nottingham; about 30 per cent. of the weight of refuse fed into the furnaces is removed as hard clinker. It requires two boilers heavily fired with refuse to produce as much steam as one boiler lightly fired with medium quality steam coal. Not the slightest nuisance has been experienced. With regard to the financial aspect, in the case of Reading, all the sewage can be pumped by water during about nine months in the year; during this time only a small quantity of cheap refuse coke is burnt, to keep boilers hot and maintain draught in chimney for the purpose of maintaining the ventilation of the outfall trunk sewer; consequently it will be seen that a large saving in cost of fuel cannot be effected. On the other hand, the handling of large amounts of house refuse and clinker necessitates considerable cost in labour. As a result the author finds that the cost of running the sewage pumping machinery will be increased by about £145 per annum by running the steam machinery throughout the year, using house refuse as fuel. During such periods as water power is not available, and steam must be used, a saving of £10 per week is effected, showing that were water power not available a large saving would be effected by the use of house refuse instead of coal. Notwithstanding that a loss is made at the pumping station by the use of house refuse, a saving is made in the cost of collection because of the convenient position of the pumping station; a large saving is also made in the cost of disposal. The net result is, that a saving at the rate of about £320 per annum is being effected, if the cost of collecting, burning about 20 tons per day, and boating about 20 tons per day to the sewage farm be compared with the cost of collecting and boating the whole of the refuse to the farm.

The sewage is pumped to Manor Farm through a 24in. cast iron rising main, having a length of 1⅝ miles. The lift from surface in pumping well to top of delivery is 48ft.

Rochdale.

The area of the district is 4185 acres, the population 72,000, and the rateable value £292,600. The town refuse is partly sifted and burned; ashes are mixed with night-soil and sold as sanitary manure. The income from this source for the year 1897 was £4130. Having a considerable surplus of refuse over and above what was necessary for the manufacture of the manure, the Health Committee of Rochdale decided to build two large Destructor cells on the best possible lines. These furnaces were arranged to be worked by forced blast, Meldrum's steam-jet blowers being used for the purpose. In these Destructors the grates are 9ft. wide and 5ft. long, and the object of this is that while one side of the fire is at a high temperature the other may be clinked or fresh charged with fuel, the result being that the gases given off are to a great extent cremated in the furnace itself. This method, combined with the combustion chamber immediately behind the furnace cell (which is 21ft. long, 7ft. high, and 5ft. wide), is found to be sufficiently effective, along with the high temperature maintained, in cremating the gases.[1]

The rate of combustion during the test hereafter mentioned was 47 lb. per square foot of grate per hour, but when necessary the quantity can be greatly exceeded.[1] Two Lancashire boilers, 30ft. by 8ft. diameter, were also fixed (one to each cell), and the working steam pressure is 120 lb. per square inch. The fuel to be burned is refuse as brought in by the carts, without any preliminary treatment. A very high temperature can be maintained, and in making tests with Siemens' pyrometer at the combustion chamber behind the cells the copper cylinders have on several occasions been melted. No cremator is used with this arrangement, and none is necessary with such a temperature in the main flue.

The following is the test above referred to:—

Evaporative Tests of Ashpit Refuse Burned in Two Cells Fitted with Meldrum Grates and Blowers, the Boilers being of the Lancashire Type, and Combustion Chambers between the Cells and the Boilers.

DATE OF TEST, MARCH 1ST, 1895. DURATION OF TEST, SIX HOURS.

Total refuse weighed	11 tons 16 cwt.
Bricks, &c., not burned	8 cwt.
Total refuse burned	11 tons 8 cwt.
Refuse burned per hour	1 ton 18 cwt.
,, ,, ,, per cell	19 cwt.
Total water evaporated	4207 galls.
Water evaporated per hour	701 galls.
Temperature of feed-water...	53 deg. Fah.
Steam pressure, average pounds per square inch... ...	113
Water evaporated per pound of refuse	1·64 lb. actual
Water evaporated per pound of refuse from and at 212 deg. Fah.	1·97 lb.
Weight of clinker produced	4 tons 3 cwt.
Percentage of clinker	36
Temperature of combustion chamber	1988 deg. Fah.
Temperature of combustion chamber after clinkering and fresh charging	1290 deg. Fah.

The steam pressure was taken half-hourly, and all the water was measured through tanks into the boilers. The steam required for the steam jets was taken from the other boilers with a pressure of 55 lb. per square inch. These results are, no doubt, chiefly due to the use of suitable steam-jet blowers for supplying air to the fuel, and not depending merely on the action of the chimney. The entire works and stables have been lighted by electricity for some years, and the power required to drive the dynamo is obtained from refuse, as in the case of the other machinery.

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[1] *Journal* of the Society of Chemical Industry.

Each cell deals with from 15 cwt. to 25 cwt. of refuse per hour, according to the labour expended. As a rule only one cell is worked at once, and steam is generated to run the manure factory, also to supply power for mortar making, manure grinding, electric lighting to the works, chopping, and corn grinding for forty-two horses; also steam power for wheelwrights' shop and smithy.

The total indicated horse-power required to run the Rochdale Sanitary Works is 120-horse power. This is for engines alone. There is also a lot of steam used for heating offices, harness-room, &c., not included in the above. The remainder of the heat is at present wasted.

The chimney shaft is 250ft. high, but was previously built for the manure manufactory.

The two cells, including two Lancashire boilers, complete, cost £1250, which is exclusive of building and chimney.

The cost of labour and supervision is 10d. per ton. Three men can dispose of 10 tons of refuse in ten hours in each of the two cells; this, with wages at 25s. per week per man, gives 7½d. per ton for labour at the furnaces; adding to this a proportion of the expenses of supervision, &c., gives the cost 10d.

The feeding and clinkering are done entirely from the front, in the same manner as an ordinary steam boiler furnace, the carts being tipped on to the floor of the Destructor building. The two operations, being carried on so close together, do not, as may be imagined, appear to tend to confusion, as the results obtained are good, the clinker hard, and the combustion perfect.

The quantity of clinker remaining after burning is about 35 per cent., and the whole is got rid of in Rochdale by making mortar, which is sold at 4s. per ton, and by the Highways Department for beds for granite-paved roads, concrete, tar-paving, &c.

An incrustation of silica forms on the inside of the furnaces, and acts as a protection to the brickwork. The manager (Mr. F. W. Brookman) has preserved a large quantity of these incrustations, taken out of the furnaces from time to time, believing the material to be of value.

The Destructors were designed by Mr. Brookman, and writing in "The Journal of the Society of Chemical Industry," April 30th, 1895, he gives the following general comment upon the design of such furnaces:—"Build your furnace cell and arrange your blast so as to burn a certain weight per hour per cell, no matter whether it be 5 cwt., 1 ton, or more, and having done this, arrange your dampers so as to prevent an inrush of cold air when the doors are opened, and you will be able to attain decidedly high temperatures, which will not only thoroughly cremate any gases distilled over at the periods of fresh charging the cell, but also at the same time generate a very large quantity of steam at a high pressure. The fact that thorough cremation of the gases and the high steam production are obtained without a cremator furnace is very important, for almost everyone knows that if you do not get complete combustion of the refuse either in the furnace or in a cremator a very unpleasant odour leaves the chimney."

Houses are built quite close up to the Rochdale Destructor Works, being separated only by the width of the street. The tub or pail system of collecting excreta is in use in Rochdale, and the quantity collected is about 10,000 tons a year, while 16,000 tons of ashes are burnt in the Destructor. When the excreta arrives in special vans at the works, it is first dried and afterwards ground fine and sold for £5 10s. per ton, at which price the manure finds a ready sale.

Rotherham.

The area of the district is 5995 acres, the population 50,000, and the rateable value £152,500. A 6-cell "Fryer" Destructor was erected in 1892 by Messrs. Manlove, Alliott, and Co., at a total cost, including cells, cremator, shafts, sheds, and foundations, of about £4000. The area of the site is about three acres, but the Destructor buildings and approaches only occupy one acre.

The cost for labour and materials of burning the refuse is from 1s. 1d. to 1s. 4d. per ton.

A boiler has recently been added for the utilisation of the surplus heat from the cells, but the steam is at present only used to create forced draught to the furnaces. It may be used later in connection with the sewage scheme.

The chimney shaft is 180ft. high.

The Borough Surveyor considers that the Destructor has not been very satisfactory, but better results are now expected from the use of forced draught.

Rotherhithe.

The area of the district is 754 acres, the population 40,879, and the rateable value £216,646. After visiting the various types of Destructor furnaces, the Vestry decided to put down a 2-cell Beaman and Deas Destructor, together with two 64-horse power water-tube boilers. The chimney shaft is 150ft. high above ground level, the contract fo which amounted to £2428.

The surplus heat will generate steam for driving mortar mills, chaff cutting, corn crushing, supplying disinfecting apparatus, and lighting the works by electricity. About 6000 tons of house refuse per annum will be dealt with by the Destructor.

The following extract from the annual report for the year ending March, 1897, of the Vestry Surveyor, Mr. Norman Scorgie, A.M. Inst. C.E., gives a *résumé* of the provision of Refuse Destructors in Rotherhithe, with the principal details of the installation:—

> The Committee appointed to inspect recently erected Dust Destructors in London and the provinces presented their report on the 7th July, 1896, the consideration of which was deferred to enable them to visit Lewisham to inspect a new form of Destructor, which was promised to be at work in a few weeks, but they were compelled to wait over seven months, and it was only on the 27th February that they were enabled to see the machine in operation. This long period of waiting was not altogether without advantage, as during that time the Destructor at Leyton, which at the date of their first report was in course of erection, was completed, and commenced working during the first week in October. The Committee were so impressed with what they saw at Leyton on the 10th December, and from additional information which they obtained from a source independent of the makers, that on the 16th February they reported to the Vestry a modification of their report of the 7th July, and unanimously recommended in favour of this form of Destructor. The report was adopted at the meeting of the Vestry on the 16th March, and the Surveyor was instructed to prepare, as soon as possible, the necessary drawings. The Destructor, which will consist of two cells, will be approached by an inclined road, with a gradient of 1 in 20, to the tipping shed, the refuse being shot into shoots, one to each cell, and the cells charged alternately so as to ensure an even temperature in the combustion chamber. The outlets to the flues are at the opposite end to the feed openings, so that the gases pass through the hottest part of the fire on their way to the chimney. The fire bars will be stationary and fixed level, and the clinker will be removed by hand through openings in the side of the cells, the clinkering floor level being 9ft. 6in. below the level of the tipping floor. Forced draught from a fan will be introduced under the grate, the ash hearth being sealed. Immediately behind the combustion chamber will be placed two 64-horse power water-tube boilers, with a by-pass flue between them, and the dampers will be so arranged that the gases pass round the tubes of one or both boilers, or direct to the chimney through the by-pass flue. The boilers will be fitted with auxiliary firing arrangements, and the steam generated by the waste heat will be utilised for disinfecting purposes, and working an engine to supply power for mortar mill and electric lighting, the engine-house and mortar mill shed being placed beneath the tipping shed. The chimney shaft will be octagonal in form, with square base, and 150ft. in height above the level of the coping of the dock, 4ft. inside diameter, with an inside lining of fire-brick for a height of 100ft.

These works are now in progress.

Royton.

The area of the district is 2112 acres, the population 15,000, and the rateable value £53,500. There is a 4-cell Destructor, erected in 1898 by Messrs. Goddard, Massey, and Warner, on a site measuring about 100ft. by 70ft., adjacent to the Sewage Works at the westerly boundary of the district.

The cells are erected in a single row, and only three of them are worked at one time, the remaining one being kept in reserve. From 4 to 5 tons of refuse are destroyed per cell per day, which is equal to the supply; more could be destroyed if required. There are two men engaged as stokers; they work in two shifts of twelve hours each, and are paid at the rate of 6d. per hour, or about 29s. per week. The cost of labour is 9½d. per ton. The works are under the supervision of the manager of the Sewage Works. The clinker, amounting to 25 per cent. of the refuse, is used for road-making.

The cells were fitted with forced draught, but this has since been abandoned. There is also a cremator heated by oil, but it is not always in active operation—its use depending upon the nature of the refuse under treatment. The refuse consists of ashpit contents, slaughter-house offal, and garbage. The area of the fire-grate is about 25 square feet, and consists of rocking bars worked by hand. Steam is raised in a multitubular boiler, 12ft. by 7ft., guaranteed for a pressure of 80 lb. per square inch, and the power thus obtained drives sludge-pressing machinery at the Sewage Works, with which the Destructor forms a joint scheme. The cells, buildings, and chimney are well built, but it is difficult to give the exact cost, being included in the joint scheme as above mentioned. The Destructor portion, however, amounted to about £4500, out of which the chimney, which is 218ft. high, cost £900.

The temperature of the cells is said to vary from 500 to 790 deg. Fah., and repairs have had to be effected to each cell, as the heat of the fire is found to affect the brickwork, &c.

Each cell is charged every quarter of an hour by the patent lever arrangement. The cells are built in brickwork, in much the same manner as others. The top of each cell is composed of several reverberating transverse arches, with a flat floor above, on which the refuse is tipped from the carts; an opening or hopper over the drying hearth in each cell is formed, through which the refuse is charged. This hopper is provided with an iron hinged door, on which the refuse to be charged rests, and by means of levers the door is let fall, allowing the refuse to drop on to the sloping drying hearth, from which it is afterwards raked down on to the fire from the front through the clinkering doors. The fumes do not pass over the fire, but are taken out at the back of the furnace through an opening in the flues, and are afterwards passed through a cremator, heated by oil jets, from which they pass on to the chimney. The openings are provided with doors, worked by levers from the front, which can be opened or closed at leisure when clinkering or charging, so as to regulate the quantity of cold air rushing in. The makers have since adopted in later Destructors the principle of taking the fumes over the hot fire and allowing the gases to enter the flues from the front of the furnace.

Elaborate filtering tanks and settling tanks are erected here for dealing with the whole of the sewage of the town. The sludge, after settling, is compressed, and then given away to the farmers, who utilise same for manure for the land.

The nearest house is about 200 yards away, and there are no complaints.

Salford.

The area of the district is 5175 acres, the population 210,800, and the rateable value £835,500. There are three Destructor stations at Salford, as follows:—Wilburn-street depôt, 12 cells; Carry-street depôt, 6 cells; Agecroft-street depôt, 6 cells. The cells are all of the "Fryer" type, improved by Mr. Geo. E. Hall, the Superintendent of the Lighting and Scavenging Department, and were erected in 1883 (North District) and 1888 (South District). The refuse burned consists of that portion of the contents of ashpits not fit for manure. Each cell is capable of consuming 8 tons in twenty-four hours, at a cost for labour only of 7·4 pence. No fuel is required in connection with the burning. There are no boilers, and the heat created is allowed to run to waste. The chimneys are 180ft. in height, and cost £558. The first 6 cells erected cost £1729 (excluding chimney); the second 6 cells erected cost £826 (excluding chimney). The first 6 cells included royalty and ironwork, £995; the second 6 were constructed by the Superintendent.

The Destructors are an improvement upon Messrs. Manlove, Alliott, and Fryer's type, the arrangement of the flues and feeding-hole having been altered, so that the fire and gases passing to the flues are kept in the centre of the furnace, and not the one on either side as in the original type. The results obtained are better both in the quantity of refuse consumed per cell and in the quality of clinker resulting. No forced draught is employed, and no nuisance from smoke or smell has ever been detected by the inhabitants from the Destructors.

The method adopted at the Wilburn-street depôt may be taken as typical of the others. Here the cesspool and pail refuse, together with road slops from paved streets, vegetable matter, putrid fish, &c., is tipped into large tanks, to which is added a sufficient quantity of fine screened house ashes and dust to bring the sloppy refuse to such a consistency that it can be handled as manure when it is placed in barges at the wharf alongside the depôt and sent into the country as manure. The remainder of the refuse, which is unsaleable as manure, is burnt in the Destructors, which reduces the bulk to 38 per cent. of the whole amount. No special attempt is made to utilise the clinker; some, however, is used for forming a foundation under paved roads, and what cannot be thus disposed of, or given away, is sent to waste heaps.

The following are the quantities, as given in the Superintendent's annual report, of refuse dealt with by the Destructors during the year 1896—7, with the clinker produced, and the cost of labour in burning:—

For the year ending March 25th, 1897.

District.	Rubbish burnt in Destructor.	Clinkers from Destructor.	Percentage of clinkers to rubbish burnt.	Furnace men's wages per ton of rubbish burnt.
	Tons.	Tons.	Tons.	Pence.
South Salford ...	15,719	6,151	39·1	7·1
West „ ...	7,706	3,130	40·6	7·0
North „ ...	12,900	4,916	38·1	7·7
Total	36,325	14,197	39·0*	7·4*

* Average for the three Destructors.

	Mineral water bottles.	Mixed bottles.	Broken glass. Tons.
Collected from the rubbish at the Destructors in 1896—7:—			
South Salford	84,648	4,344	34
West „	41,520	8,532	19
North „	40,296	6,096	22
Total...	166,464	18,972	75

	1896—7.
Number of dead animals cremated for the police	172
Do. do. Ship Canal Company	5371
Total	5543
Number of pounds of bad meat burnt by order of the Meat Inspector	97,126

Sheffield.

The area of the city is 19,651 acres, the population 347,278, and the rateable value £1,239,450. A 6-cell Destructor has recently been erected by Messrs. Goddard, Massey, and Warner. Ordinary ashbin refuse is burnt at the rate of ten tons per cell per twenty-four hours. As the Destructor has only recently come into full operation, the cost per ton of burning the refuse has not yet been ascertained. The surplus heat generates steam in a boiler 11ft. by 6ft. 6in., working at 80 lb. pressure per square inch—the steam being utilised for grinding mortar, driving forced blast to cells, and it is proposed to light the buildings and yard by electricity.

The chimney shaft is 180ft. in height. The total cost of the works, exclusive of site, has been between £9000 and £10,000.

The use of Destructors is about to be extended, and another plant will be erected in another part of the town. It has been decided to adopt the Beaman and Deas system.

Shoreditch.

The area of the district is 648 acres, the population 124,000, and the rateable value £693,732. The Destructor installation at Shoreditch is one of a number of municipal undertakings recently carried out by the Vestry, and was opened by Lord Kelvin on the 28th June, 1897. Upon the same site (Pitfield-street) there has been erected a Central Electricity Station, worked by steam supplied from Destructor cells, Public Baths and Washhouses (heated from the Destructor), also a Public Library and Museum.

Towards the end of 1892 the Vestry retained Mr. E. Manville, of Messrs. Kincaid, Waller, and Manville, to report to them on the best method of carrying out an Electric Light Provisional Order they had obtained. At the same time the Vestry, having in view the excessive cost of disposing of the ashbin refuse of the parish, desired their engineer to consider the practicability of combining a Dust Destructor with the Electric Light Station, in which the refuse could be burnt and the heat produced utilised for the production of steam.

The subject received careful consideration from the engineer, who was accompanied by a deputation of the Electric Light and Scavenging Committees to many Dust Destructor installations in the kingdom, and from the information thus gathered, and from experiments made in burning samples of the Shoreditch refuse, a report was presented to the Vestry recommending the combination to be carried into effect, pointing out that the refuse could be burnt at a smaller cost than that at the time incurred by the Vestry in otherwise disposing of it, and that a large amount of steam could be

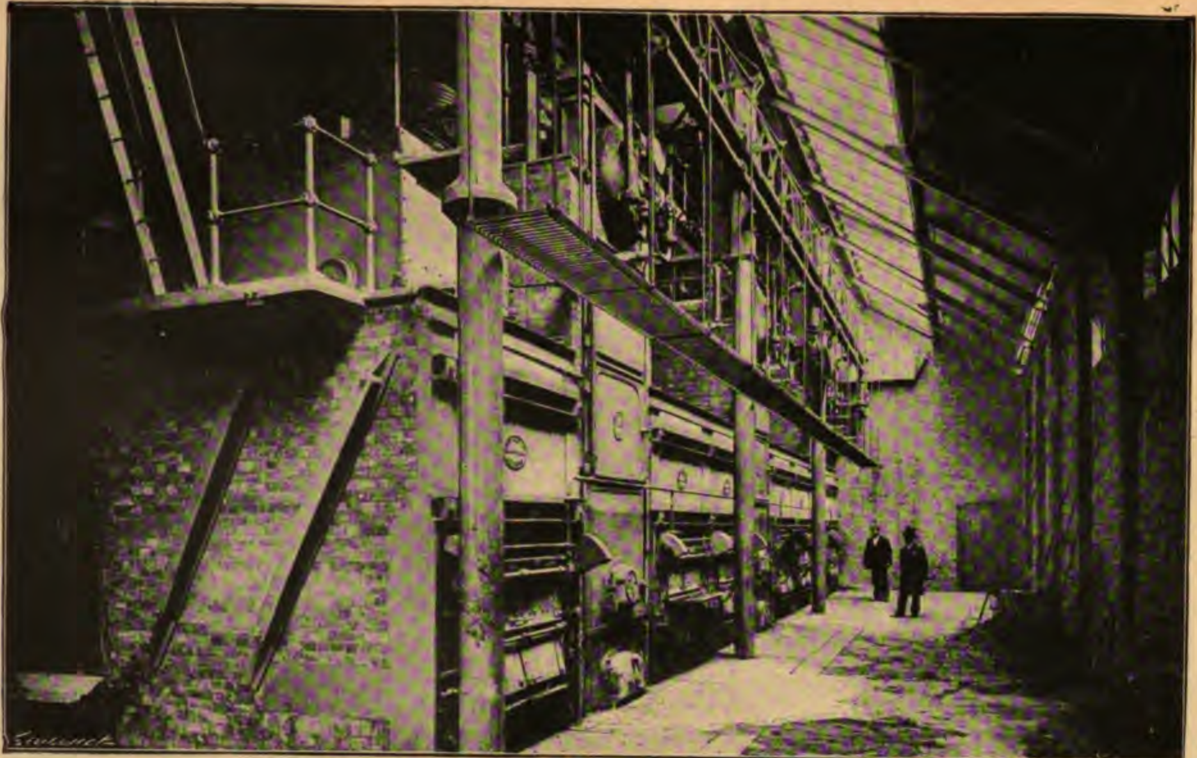

Fig. 162a—SHOREDITCH DESTRUCTOR WORKS—VIEW SHOWING CELLS, BOILERS, &c. [Face page 324]

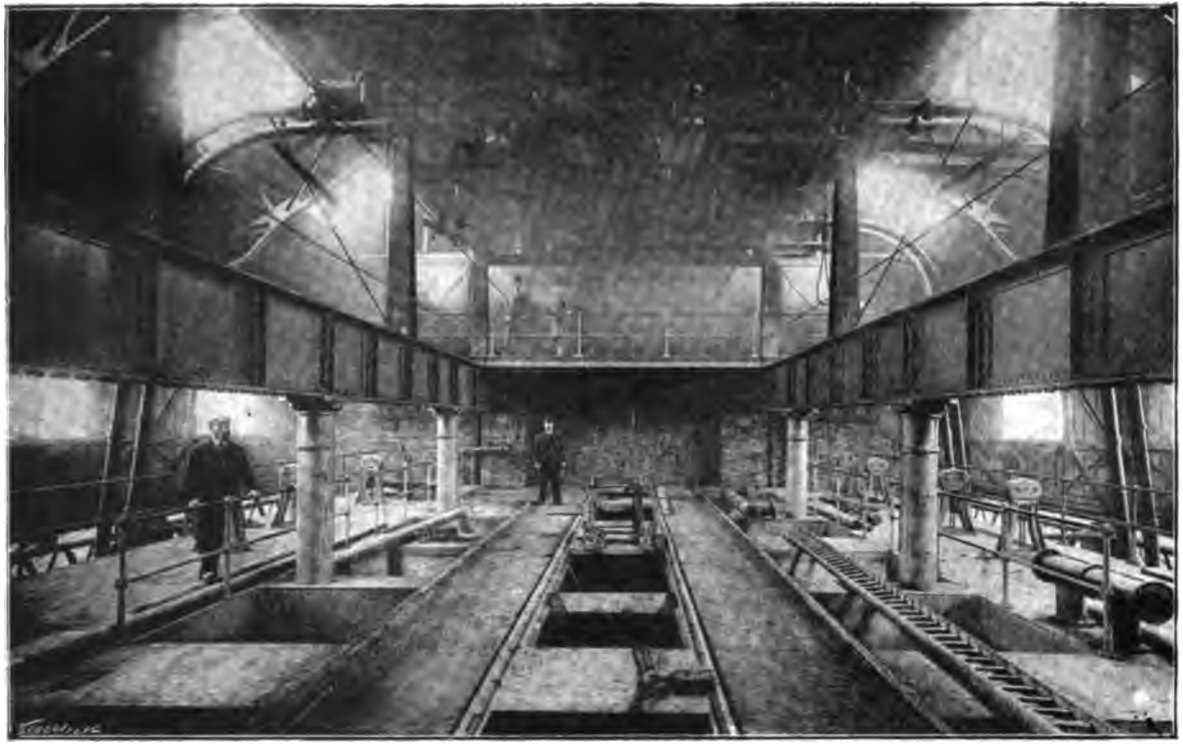

Fig. 62b.—SHOREDITCH DESTRUCTOR WORKS—TIPPING PLATFORM AND THERMAL STORAGE CYLINDER.

[Face page 324

produced from its combustion, thus saving the Electric Light Station in coal, and also in the wages of stokers.

This report was adopted by the Vestry, but a long time elapsed before it was decided to proceed with the actual construction of the works. In the meantime a very desirable site was found in the very centre of the parish, large enough not only for the erection of the Dust Destructor and Electric Light Station, but also for the erection of the Public Library, Baths, and Washhouses, &c., referred to above. This site having been secured, the Vestry instructed Messrs. Kincaid, Waller, and Manville to prepare the specifications for the carrying out of the combined scheme, and the following is a list of the contractors who obtained contracts for the different sections of the work:—Buildings, Messrs. Atherton and Dolman; Dust Destructor, with boilers, fans, lifting gear, and chimney shaft, Manlove, Alliott, and Co.; dynamos, engines, motor transformers, switchboards, and public lighting, Messrs. The Electric Construction Company; conductors and conduits, British Insulated Wire Company and Messrs. W. T. Glover and Co.; steam pipes, steam, exhaust, feed pipes, tanks, and pumps, The Thames Ironworks Company; battery of accumulators, Messrs. Pritchetts and Gold.

The following is a description of the various sections of the work:—The buildings consist of a Destructor-house and engine-house, with suitable offices, pump and fan room, and accumulator room. The engine-house is 68ft. long and 46ft. broad, and is arranged with the high-tension continuous current sets on one side, and the low-tension sets and station motor transformers on the other side. A wide gallery is provided against one wall of the engine-house to accommodate three switchboards. Off the engine-room is a test room, in which are erected all the testing instruments, and which, in addition, is used for the calibration of meters. The offices, which front the street at the end of the engine-room, contain suitable accommodation for the Electric Lighting Committee, the engineers, and for ordinary office purposes. In order to prevent, as far as possible, vibration from the running of the engines, the whole floor of the engine-house has been made a solid mass of concrete, about 10ft. in thickness, and the surface of this is tiled over in a neat manner.

The Destructor-house is a building 80ft. by 80ft., with a roof of unusual shape and dimensions, specially designed by the engineers, and forming a portion of the covering for the sides of the buildings in place of carrying the brick walls right up to the usual heights. There are also provided bath-rooms for both the engineers and the workmen, and accommodation for the men for taking their meals, and so forth.

The interest attaching to the Shoreditch works lies in the combination of both schemes—undertaken at one and the same time with the express purpose of elaborating the one to suit the other—and thus involving arrangements peculiar to this installation, at the same time not forgetting that the steam requirements of the electric lighting station must be treated as of secondary importance in comparison to the hygienic manipulation of the refuse. A further novelty is the combination of Mr. Druitt Halpin's system of feed thermal storage and the substitution of electric lifts and motor cars for revising and distributing refuse throughout the cells in place of the more usual inclined road and tipping platform, thus effecting a considerable saving in horseflesh. A general idea of the size of the plant may be gathered from the following figures:—The Destructor-house is 80ft. square, and contains 12 cells, each having 25 square feet grate area, and six water-tube boilers, each with 1300 square feet of heating surface. The boilers and thermal storage vessel (which is 35ft. long and 8ft. diameter) are designed to work at a pressure of 200 lb. per square inch, and are supplied with duplicate fittings throughout to guard against breakdown. There are three motor-driven fans calculated to deliver each 8000 cubic feet of air per minute, with a maximum ashpit pressure of 3in. of water. The chimney is 150ft. high and 7ft. internal diameter at the top, jacketed with fire-brick throughout, and surrounded at the base with a centrifugal dust-separating chamber. The whole of the dust Destructor and steam generating plant were designed under Messrs. Wood and Brodie's patents, and were erected by Messrs. Manlove, Alliott, and Co., Limited.

The gases from the cells pass out of each cell at the front, thence through the boiler tubes and out at the back of the boilers into either of the two main flues leading to the settling chambers and chimney. Wherever required each boiler may be shut off, by means of dampers, entirely free from each or both, of its adjacent cells, and may also be fired at all times independently with coal or any other suitable fuel. Again, the cells may be worked independently of the boilers, but in this latter contingency the gases pass out from the cells at the back and not at the front. Owing to this arrangement, the cells may be repaired independently of the boilers, and the boilers may be repaired independently of the cells; moreover, in the event of refuse not being collected or being deficient from any cause whatsoever, steam may still be raised in the same manner as is adopted in any other electric lighting boiler-house, viz., by means of coal. The cells themselves are not charged with refuse by hand, but by means of Boulnois and Brodie's patent charging trucks. This arrangement is novel as arranged at Shoreditch, although the principle has been adopted in many other district stations.

It should be noticed that it is possible for one man to keep the whole of the twelve cells charged at regular intervals, and, moreover the refuse is never left to ferment or heat on hot brickwork or ironwork. It is always kept cool and thoroughly well ventilated by means of artificial draught provided by the fans. Another peculiarity of the cells is, that the forced blast may be produced either by means o motor-driven fans or with the agency of the steam jets. It is noticeable that the whole of the air that enters the building is taken from it by means of these forced-draught fans and carefully burnt before allowing it to proceed up the chimney. A double purpose is therefore served—the building is well ventilated, and no nuisance can arise so far as the neighbours are concerned. A connection has also been made from the adjoining sewer to the intake of one fan, which constitutes an experimental effort to ventilate the sewer by passing the gases abstracted therefrom through the fires and thus rendering them innocuous.

Returning to the boilers, it may be mentioned that steam is generated at all hours during the twenty-four, owing to the necessity of burning refuse continuously, and the working conditions are therefore essentially different from those prevailing in the ordinary coal-fired boiler-house. On the other hand, light being required on a large scale only during some four to six hours out of the twenty-four, it is obvious that without some system of heat storage a vast amount of valuable steam would be wasted.

With the arrangements at Shoreditch, during the day time, steam generated in the boilers is passed into a *thermal storage cylinder*, where it is mixed with a small quantity of cold water from the feed pumps, the proportions being such that when the evening approaches the cylinder is full of water at the temperature and pressure of the steam required by the engines. The cylinder is then shut off from the feed pumps and connected to the boilers, which in their turn are connected direct to the engines; hence, when the boilers require feed-water they are supplied with it from the cylinder at such a temperature that the fuel that is then being burnt has merely to furnish to the water in the boilers the heat sufficient to overcome the latent heat of evaporation at the required pressure. The result of this arrangement is that the boilers are able to evaporate about one-third more steam than they would be able to evaporate were they connected directly with the water mains, and moreover gases can be sent away from the boiler at such a low temperature that they would be useless for the purposes of even an economiser. The importance of the thermal storage cylinder is further enhanced by the fact that it acts as a water purifier.

One of the main drawbacks to the use of water-tube boilers has always been overcome by the use of clean or softened water, but if the feed-water be first raised to 350 deg. Fah. in the thermal storage cylinder, the deposit will occur mainly there, and clean water will be delivered to the boiler. Curiously enough, the presence of scale in the cylinder will tend rather to improve its efficiency than otherwise, for the radiation losses will diminish.

The capacity of the cells is from 8 to 12 tons of refuse per cell per day. The combined arrangement of cells and boilers is designed so that when ten cells and five boilers are in use the average evaporation per hour from refuse only will about equal the average quantity of steam required by the engines throughout the whole of the twenty-four hours.

The total horse-power of boilers installed for use with heat from the cells is about 1200. The cost of the Destructor works was about £14,000.

In a report[1] of a deputation of the Borough of Darwen, drawn up after a visit of inspection of these works, it is observed that:—

> Despite the rumours that coal was being very extensively used in conjunction with the refuse—a rumour which has given very great offence to the Committee and officials—we are assured that coal has only been used at week-ends, as it was found impossible to keep over sufficient refuse from the supply that came in, but were informed that when the coal was used it was not mixed with any refuse, but used directly under the boilers, in the proper fire-grates provided for that purpose.
>
> The amount of coal consumed each month is officially stated to be from 25 to 30 tons, which averages about seven tons per week-end, and we cannot but think that this amount is somewhat excessive for the units generated during that period.
>
> With regard to the thermal storage system, we made careful inquiries, but were informed that this has only been in use for about a fortnight, and the engineer told us that the reason for its discontinuance was not through any failure in the principle, but was due to a detail in the construction, rendered necessary by the Insurance Company's regulations.

These works undoubtedly demonstrate what valuable use can be made of the refuse of towns in circumstances similar to Shoreditch, where there is a dense population on a limited area, or a large quantity of refuse to be disposed of and a confined area to be lighted.

Sowerby Bridge (Yorks).

The area of the district is 578 acres, the population 12,000, and the rateable value £48,930. The sanction of the Local Government Board has been obtained for a 2-cell Destructor, by Messrs. Manlove, Alliott, and Co., which is calculated to burn six tons of combined midden-closet and ashpit refuse per cell per twenty-four hours, at an estimated cost for labour of 1s. 2d. per ton. The surplus heat is proposed to be utilised in the manufacture of mortar. The shaft is 140ft. in height, and the cost of the works, exclusive of site, £1829.

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[1] Dated December 3rd, 1897.

Southampton.

The area of the district is 5295 acres, the population 100,000, and the rateable value £413,521. The sewage and dust of the town are both dealt with at the same centre upon an economic system. After the sewage has been clarified with chemicals, the sludge is mixed with the road sweepings, fine ashes from the Destructor, or sorted house refuse, and sold as manure to agriculturists at about 2s. 6d. per load.

There are at present ten Destructor cells in operation, but three more are now in course of erection at outlying stations. Six cells were erected by Messrs. Manlove, Alliott, and Co., in 1886, and the remaining four by Messrs. Goddard, Massey, and Warner in 1895. The material dealt with consists of ordinary house refuse; the *maximum* consumption is fifteen tons per cell per twenty-four hours; but the amount varies considerably, according to the quality of the refuse and the state of the weather. The cost in labour for burning is 6d. per ton. The total horse-power of boilers installed for use with the surplus heat from the Destructor cells is 150, but another boiler of 100-horse power is now being inserted.

The steam generated is used for pumping about three million gallons per day of sewage through a 20ft. lift, for air-compressing for Shone's ejectors, which are used for lifting the sewage effluent and sludge from the precipitating tanks, and also sewage and storm water from low-lying sewers, for driving mortar mills, for generating electric light for the sanitary works, and for supplying power for chaff-cutters, &c., and smiths' forges. The multitubular steam boilers erected over the newer furnaces are capable of generating steam at 160 lb. pressure, and, with the additional boiler capacity, it is calculated that sufficient steam power will be obtainable from the burning of the refuse for the purposes of pumping and chemically treating the sewage, &c., without the aid of other boilers fed by coal. The Destructor station is a mile from the precipitating tanks. The tipping platform extends all round the furnaces, so that there is no blocking in of the carts after discharging their loads. The air-compressing engines keep up a pressure of 70 lb. or 80 lb. per square inch in the reservoir by day when the ejectors are discharging every three hours. At night and on Sundays the pressure is allowed to fall 30 lb. on the square inch, and it can soon be increased if any demand on the pumping power of the ejector arises. Forced draught is applied to the four cells last erected, but not to the older Destructor. There is no cremator.

Some of the clinker is made into mortar and sold at 7s. per ton, at which price there is a good demand. A portion of the clinker is used for making concrete for Corporation work, and some is made into concrete slabs for street paving, and the remainder is sold at 2d. per ton. The chimney shaft is circular and 160ft. in height from the ground line; the inside diameter at the bottom is 7ft., at the top 6ft.; the shaft stands upon a pedestal, 14ft. 6in. square and 24ft. in height, of brickwork 3ft. thick. The shaft then consists of four sections as follows:—

1st	section,	30ft.	high, is of	brickwork,	27in.	thick.
2nd	„	30ft.	„	„	22½in.	„
3rd	„	38ft.	„	„	18in.	„
4th	„	38ft.	„	„	14in.	„

The first 30ft. is fire-brick lined, with a 4½in. cavity behind, ventilated to the outer side. The foundation is loamy clay, upon which is laid a bed of concrete, 30ft. square and 10ft. thick. The footings commence at 23ft. 2in. square and step off in regular courses up to 15ft. square at a height of 6ft. The concrete was filled in continuously until completion. The pedestal was then run up and allowed to remain for nearly three months during the winter, after which the works proceeded until completion, which occupied about six months. The cap is white brick in cement, with a string course about 20ft. below the top. Foot irons are built inside in a winding lead to the top. The shaft is provided with a copper tape lightning conductor, with inch rod and crow's foot above the cap. The tape is about 215ft. long, the end being carried into a well. In August, 1888, the shaft was damaged by lightning, but was easily repaired. The shaft was plumbed and found to be quite vertical. The fires were only damped down during the repairs, which occupied about eight days.[1]

The initial cost of the 6 cells first erected, including engine-house, inclined roadway, chimney shaft and boiler, and ironwork complete, was £3723; and the total cost of the entire installation of 10 cells has been about £7000.

Stafford.

The area of the district is 1084 acres, the population 20,300, and the rateable value £71,033. There is a 4-cell Destructor, erected by Messrs. Manlove, Alliott, and Co., Limited. Two water-tube boilers, of the Wood and Brodie type, utilise the heat from the cells by generating steam for driving the sewage pumping machinery. Eight tons of moderately dry house refuse are destroyed per cell per day, at a cost for labour of 9d. per ton. The chimney is 135ft. high. The cost of the Destructor, duplex feed-pump, injector, connections, fan, engine, &c., was £2815. The building in which the Destructor is placed was erected twenty years ago for another purpose, also the chimney, all of which have been adapted to receive the Destructor and the sewage-pumping plant.

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[1] Paper on "The Utilisation of Town Refuse," &c., by W. B. G. Bennett, C.E. (May, 1889.); "Proceedings" of the Association of Municipal and County Engineers.

St. George-the-Martyr.

The area of the district is 284 acres, the population 60,300, and the rateable value £286,250. A special committee of the Vestry are considering the advisability of erecting a Destructor, but nothing definite has yet been settled.

St. Helens.

The area of the district is 7248 acres, the population 84,730, and the rateable value £829,780. There are at present two small Destructors at the Parr depôt which are similar to the ordinary gas furnaces which are used in the district, and which destroy a little over five tons per cell per day, leaving a good clinker. The cost of erecting the furnaces was about £60 per cell, not including the chimney or boiler for forced draught.

Better class Destructors are about to be erected, and it has been decided by the Council to put in four cells of the Beaman and Deas type, from which, it is hoped, will be obtained sufficient power to generate electricity for some ten miles of tramway system.

The Borough Engineer, Mr. Geo. J. C. Broom, C.E., is now preparing plans for the erection of these Destructors, and also a pail-house and engine and dynamo house for the electric traction, together with a new chimney 200ft. high.

These Destructors will be very carefully tested after they have been completed by an independent expert, and, if successful, further tests over a lengthened period will be carried out by the Borough Engineer.

St. Luke.

The area of the district is 237 acres, the population 41,527, and the rateable value £358,400. A 6-cell Destructor was erected in 1895 by Messrs. Goddard, Massey, and Warner, of the "Warner's Perfectus" type.

St. Pancras.

The area of the district is 2672 acres, the population 240,770, and the rateable value £1,648,200.

During the years 1894—5, the St. Pancras Vestry erected at King's-road, Camden Town, works which combine two of the most important

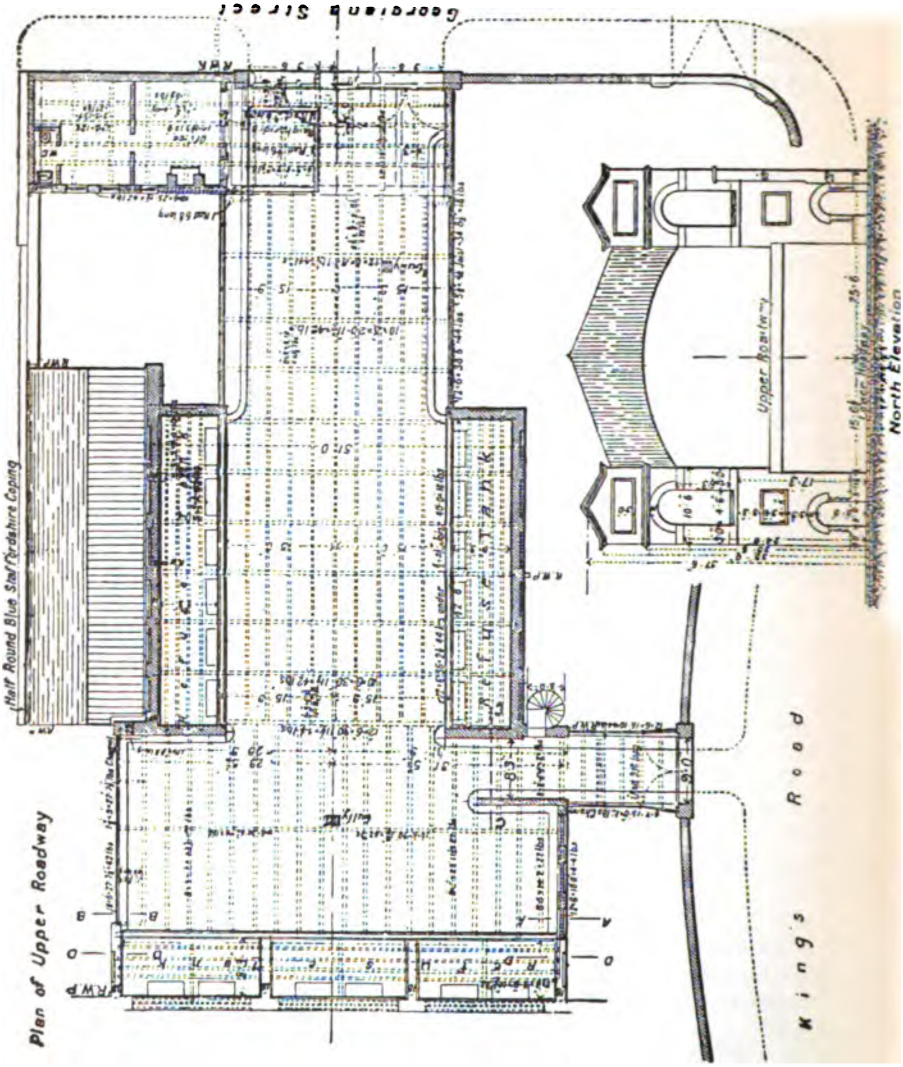

Fig. 88.—St. Pancras Destructor Works—Plan.

operations which devolve upon Local Authorities, namely, the destruction of house refuse and the generation of electricity for public supply. The works are erected on the same site, and the two operations can be carried on either in conjunction with one another or quite independently.

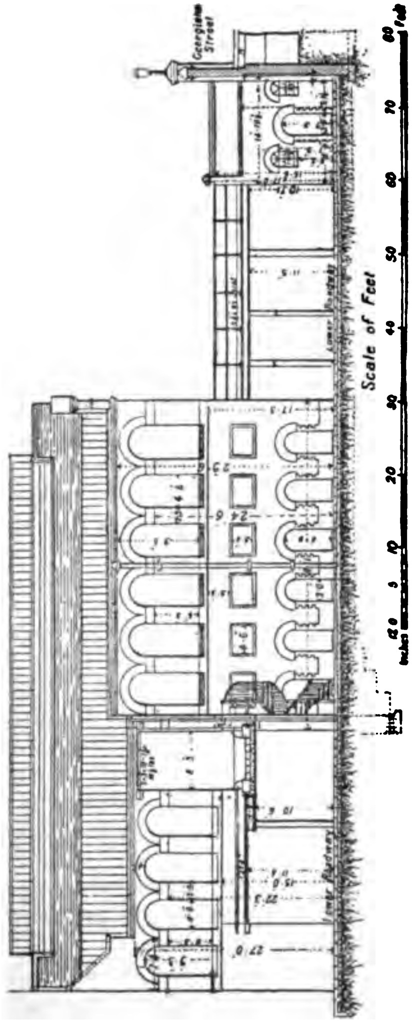

Fig. 84.—St. Pancras Destructor Works—East Elevation

The question of the disposal of the dust-bin refuse in St. Pancras by means of Destructors was under the consideration of the Vestry as far back as the year 1876, and for several years the matter was investigated by a special committee under the chairmanship of Mr. Nathan Robinson. In 1891 the late Chief Surveyor, Mr. Booth Scott, reported to the Vestry on the cost of the disposal of the refuse and road sweepings during the preceding ten years, and in that year the proposals that had been often made that the Vestry should take into its own hands the disposal of the refuse of their district assumed a definite shape, and a committee was authorised to proceed on those lines. At this time the Vestry had carried out an installation of electric lighting under Professor Robinson, who suggested, in view of the large demand for electricity throughout the district, that a combined electricity and Refuse Destructor station could with advantage be carried out for the purpose of utilising the waste heat from the Destructors in connection with the boilers to generate electricity. Professor Robinson and Mr. William Nisbet Blair (the then newly-appointed Borough Engineer) recommended early in 1893 the carrying out of a joint installation at King's-road, and a special committee advised the Vestry to adopt this recommendation.

The site purchased by the Vestry for the combined works covers an area of 28,000 square feet, but the present works only occupy about 24,000 square feet; the remainder—being under leases not yet expired—will be available for ultimate extensions of the electricity works. There are frontages on three sides of the site at different levels which are particularly convenient for dealing with the dust-bin refuse and the clinker from the Destructor furnaces. Fig. 63 shows the general arrangement of the works.[1]

The north frontage is in Georgiana-street, at a high level, affording access for the dust carts to the top of the furnaces. The south frontage is at a lower level, and provides an entrance with a short inclined roadway to the Destructor yard, and also a level entrance to the engine and dynamo-house. The east frontage is in King's-road, and is utilised for an exit for empty dust-carts and for an entrance to the electricity works and coal store. A subway, 50ft. long, 11ft. wide, and 10ft. high, under Georgiana-street, on the north, connects the works with Bangor Wharf, on the Regent's Canal. A chimney shaft, 207ft. 6in. in height (Fig. 65), was constructed to serve both for the Destructor station and for the electricity installation, Messrs. Kelly Bros., of Liverpool, being the contractors.

The shaft stands upon a concrete foundation, 36ft. square and 8ft. in thickness, resting upon the London clay at a depth of about 23ft. 6in. below the ground surface. From this base the shaft rises square to form a pedestal, 21ft. wide each way, the brickwork of which

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[1] The illustrations of the St. Pancras works have been kindly lent by *The Engineer*.

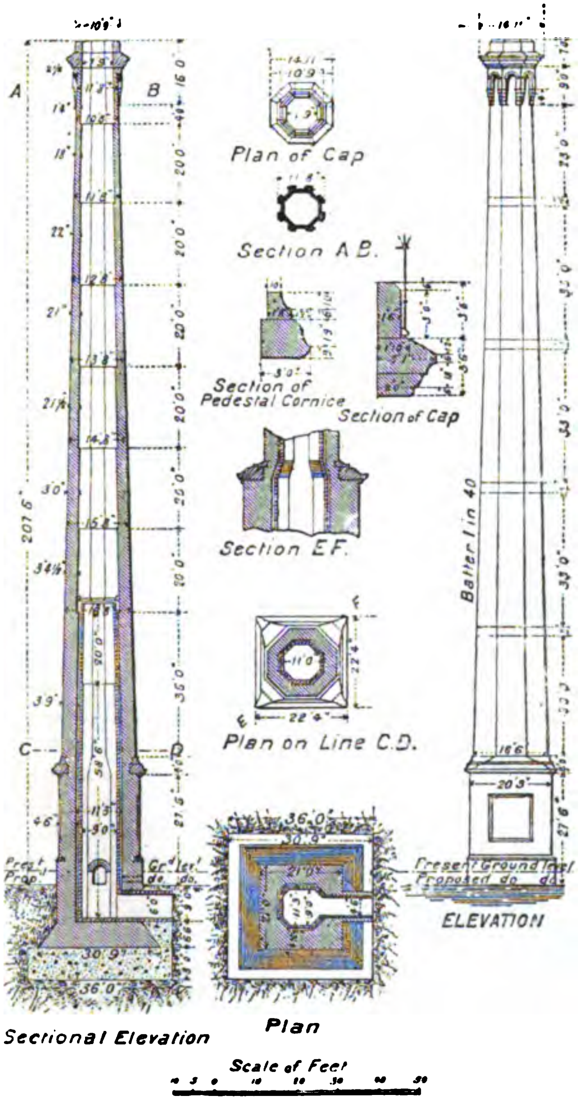


Fig. 65.—St. Pancras Destructor Works—Chimney Shaft.

is 4ft. 6in. in thickness. From this pedestal an octagon shaft is carried up to an ultimate height of 231ft. above its foundation. The shaft is built with stock bricks and Ruabon red brick quoins and strings. The capping is formed of Derbyshire stone, three courses in depth and eight stones in each course, which are all cramped together with copper cramps. For a height of 80ft. from the bottom of the flue the shaft is lined with fire-brick, between which and the main structure a 3in. cavity is left, ventilated with openings from the outside, to prevent the heat being communicated to the main brickwork of the shaft. The diameter of the flue is 9ft. at the base and 7ft. 9in. at the cap.

The main block of Destructor buildings is 80ft. in length by 51ft. in width, and 30ft. above the ground to the eaves, forming two stories, the lower one containing the furnaces and the refuse tanks, together with passages between them giving access to the furnaces, the upper storey consisting merely of a paved roadway 30ft. wide, by which the vans bringing the refuse have access to the refuse tanks, one of which is situated on each side of this roadway, and three smaller tanks at the south end of the block. The roadway is on a level with Georgiana-street, and at the entrance is placed a 10-ton weighbridge, by Messrs. Avery and Co. An additional exit for the empty vans is provided on the east side, leading down a short incline to King's-road.

The Destructor plant consists of eighteen furnaces, together with the necessary flues, both above ground and under ground, to conduct the hot gases where required, and eventually to the chimney shaft. It includes also the refuse tanks and provisions for all the machinery required in the depôt. This work was carried out by Messrs. Goddard, Massey, and Warner, of Nottingham.

Six furnaces are placed on each side of the main building and under the upper roadway, and six more are placed in pairs at the south end of the block, all the furnaces being connected to the refuse tanks by iron hoppers, by which the refuse passes from the tanks to the back of the furnaces. The form of construction of the furnaces is not that to which Messrs. Goddard, Massey, and Warner's name has been attached for some years, but is a design of the Borough Engineer's (see Fig. 66) based upon examination of various forms of furnaces. He has aimed at avoiding disadvantages in other arrangements, and in securing as far as possible the greatest efficiency in the working of the furnaces by consuming as much refuse as possible without causing a nuisance, and in producing a continuous high temperature. He also avoids as far as possible the manipulation of the refuse in the fires, by the adoption of the Healey mechanical stoking fire-bars. The principal points with reference to these are—that every alternate bar moves continuously upon a cam shaft at the back end of the cell and slides on a dead plate at the other end, the object being to carry forward the refuse at a rate found suitable to the consuming capacity of the furnace. Into these bars are coupled—by knuckle joints—

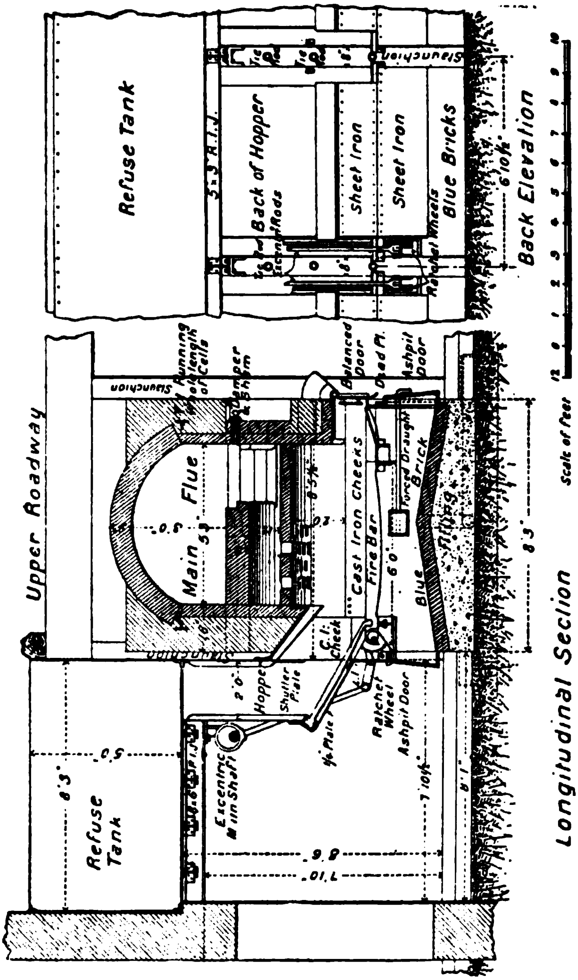
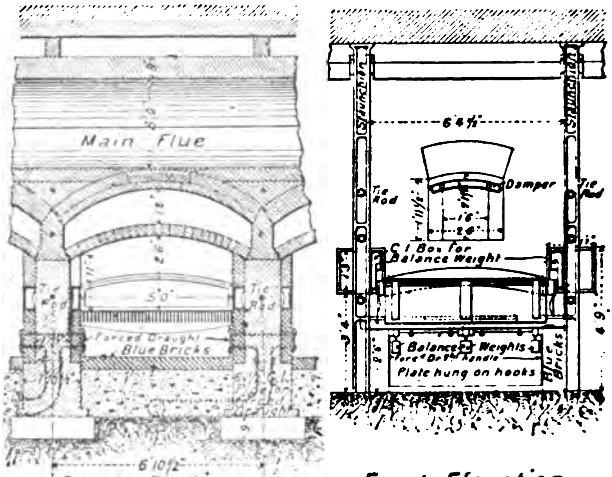


Fig. 66.—St. Pancras Destructor Works—Sections through Cells, Main Flue, &c.

shorter bars at a steeper inclination, and placed at the bottom of the hoppers. These bars also assist in carrying the material forward to the furnaces. The intermediate bars of both the front grate and the back grate do not move.

The moving fire-bars of twelve cells are operated by shafting from the engine-room, where the source of power is a 24-indicated horse power Chandler's silent engine, which also drives two mortar mills and a stone-breaker for breaking up into macadam any old granite setts that are unsuitable for re-dressing. The remaining six cells at the south end are served by a small donkey engine.

The engine-room also contains two small vertical engines of Goddard, Massey, and Warner's make, provided to drive separately two Sturtevant blowers, which supply forced draught to twelve furnaces. These blowers are set below the floor level, so that the delivery from them may pass in a straight line to 18in. pipes laid underground without any bends; the air is supplied to the furnaces by means of ports on each side of the ashpits, the ports being provided with shutters to stop the draught during the process of clinkering the furnaces or clearing out the ashpits.



Cross Section

Front Elevation

Fig. 66.—St. Pancras Destructor Works—Section through Cells, Main Flue, &c.

The design of the Destructors has, since their erection, been altered by the removal of the feeding bars, and by the addition of a solid back hearth. About 7½ to 8 tons of house refuse per cell are dealt with, at a cost of about 1s. 8d. per ton. The surplus heat generates steam for mortar grinding, stone breaking, and for the fans for forced draught. The works adjoin the Electricity Station, but now are

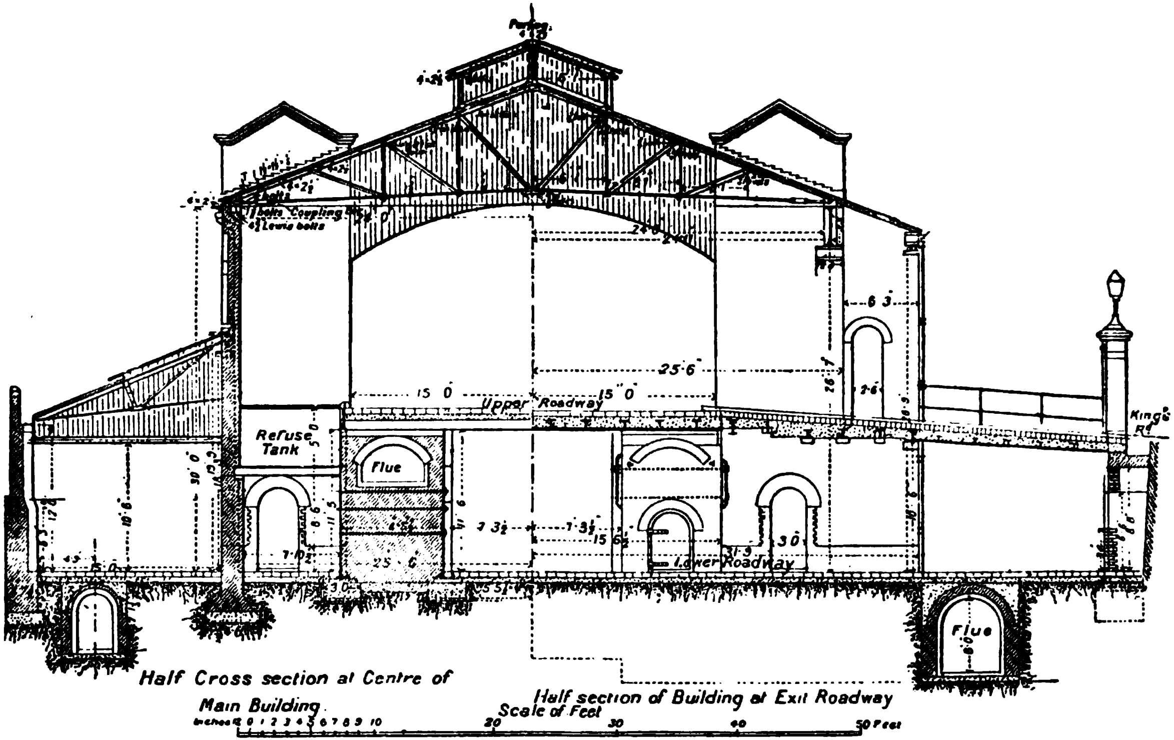


Fig. 67.—St. Pancras Destructor Works—Cross-section of Destructor Building.

worked separately; the horse-power of the boilers installed for use with heat from cells is about 100; the cost of the Destructor Works was £19,000. The fan draught employed is equal to about 1in. water gauge; with greater pressure the consumption would be much increased.

The *Public Health Engineer*, April 16th, 1898, observes that—

> The elaborate system of refuse destruction in operation has hitherto not been regarded with any degree of satisfaction in its relation to the Vestry's electricity works, although the former was designed to be worked in conjunction with the latter. It is, however, satisfactory to note from the report of the Refuse Destructor Committee that since the reconstruction of the cells, the available heat has proved to be in excess of what is required for the purposes of the Destructor works pure and simple. The chief electrical engineer has investigated the matter, and is satisfied that the Destructor can supply the electricity station with heat for some of the machinery. As to the actual amount of heat which can be supplied from the Destructor to the station, the engineer has promised to make a test in regard thereto and to report the result.
>
> Pending the presentation of the promised report, Mr. Joseph Thornley, the chairman of the Committee, mentioned that already a certain quantity of waste gases had been utilised for raising steam in the boilers, and that the production of 437 electrical units could be credited as having resulted from steam generation in that manner.

Streatham.

The Wandsworth District Board of Works for the parishes of Streatham and Tooting are erecting four Destructor cells of the Beaman and Deas type, which are guaranteed to destroy not less than 15 tons per cell per twenty-four hours.

The surplus heat is to be utilised for lighting the premises and actuating hydraulic feeding machinery. The Destructor is not laid down in connection with an electric installation, but this will probably be added in the future.

Boilers of 150-horse power are installed for use with the heat from the cells.

The chimney shaft is 150ft. in height, and the total cost of the works will be about £7000.

Stretford.

The area of the district is 3256 acres, the population 26,000, and the rateable value £154,550.

Two Destructor cells of the Beaman and Deas type are in course of erection for dealing with dry refuse from ordinary dust-bins. The surplus steam is to be used for hay chopping, clinker grinding, and for a steam disinfecting chamber.

Boilers of 85-horse power are installed for use with the heat from the cells. The chimney shaft is 150ft. in height.

The cost of the works is as follows:—

Two cells and boiler	£1481
Buildings, disinfecting chamber, &c....	2727
	£4208

Sydney.

The question of the erection of Refuse Destructors has recently been under consideration, and the Borough Engineer, as the result of his inquiries made in regard to the subject in England and on the Continent, has recommended the furnace of Messrs. Goddard, Massey and Warner as being the most suitable for use in this town.

Tiverton.

The area of the district is 17,680 acres, the population 10,900, and the rateable value £51,903.

A deputation from the Town Council recently visited the chief types of Destructor furnaces throughout the country, and, as a result of their investigations, came to the following "general conclusions":—

> In the course of our inspection we have seen quite enough to convince us that the Destructor is a cleanly and economical method for the disposal of household and other refuse, and we are unanimously of opinion that, properly worked, no nuisance need arise from it.
>
> As to the best type of furnace for the requirements of this town, we cannot at present speak in such positive terms, most of those we saw possessing some feature of which we approved.
>
> We would recommend that the following firms be invited to submit proposals and prices for the erection of a Destructor suitable for the requirements of this town, and we shall then be able to weigh the relative advantages of the various types of furnaces, with the prices submitted:—The Beaman and Deas Syndicate; Messrs. Coltman and Son; Messrs. Goddard, Massey, and Warner; the Horsfall Furnace Company; Messrs. Manlove, Alliott, and Co.
>
> On the question of cost we cannot at present give exact particulars, but we estimate approximately that a Destructor sufficient for Tiverton may be erected for £500

Cost of chimney, say 120ft. high	200
Purchase of land...	200
Buildings, which need not be of an expensive character ...	300
Machinery, boiler, &c.	200
Contingencies	100
	1500

We consider that two men in the day time and one at night will be sufficient for three days a week to work the Destructor and the machinery, which will amount to, per annum, say	£80
Interest and repayment of £1500 in twenty years	100
Repairs, say	30
	210
The value of the power for mortar grinding, stone breaking, sale of clinker (or value of same if utilised for concrete slabs), may safely be taken at, per annum	100
	110
From this should be deducted the present cost of carting away and burying the refuse after the ashes have been sifted from it, and the rent of refuse tips, say	55
	55

Leaving net cost to the borough of the Destructor plant at £55 per year, which sum, we consider, is a small amount to pay for the undoubted advantages accruing to the public health of the town by the prompt destruction of the refuse.

Todmorden.

The area of the district is 12,755 acres, the population 24,900, and the rateable value £105,850. The Corporation has decided upon, and sanction of the Local Government Board has been obtained for the necessary loan for the erection of a 2-cell Destructor in the gasworks yard, with allowance for future extensions up to six cells, and for a boiler-house.

Torquay.

The area of the district is 1465 acres, the population 26,000, and the rateable value £188,000. A 4-cell "Warner" Destructor is in course of erection, with all the latest accessories, including electric light, mortar mill, clinker mill, and stone crusher. The chimney shaft is 150ft. high.

The total estimated cost, exclusive of site, is £6146.

Wallasey.

The area of the district is 3408 acres, the population 45,000, and the rateable value £241,292. A Fryer's patent Refuse Destructor, with Boulnois and Brodie's patent charging apparatus, together with Jones's fume cremator, has been in use for fourteen months. There are six cells with a grate area of 40 superficial feet, and six cells are to be added, the contract having been let to Messrs. Manlove, Alliott, and Company, Nottingham. There is no forced draught, only that which is provided by the chimney stack. The Destructor building was built large enough for twelve cells, and the cost was as follows:—

	£	s.	d.
Cost of building and chimney	4820	14	9
Cost of Destructor proper, flues, cremator, and boiler	3196	19	2
Total	£8017	13	11

Thirty-eight tons of refuse from ashpits, &c., is collected per day, and the work is let by contract, the contractor being paid at the rate of 2s. 6d. per ton. Every ton is weighed as it enters the yard. Each cell consumes 6¼ tons per day. Four stokers are employed at 26s. per week, also four night men at the same wages. The cost of labour and attendance for the fourteen months is £832, which equals 1s. 6·37d. per ton. Rocking bars underneath each cell have been provided, and are worked by hand; the chimney stack is 160ft. above yard level, and 175ft. from foundation. The maintenance up to date has been in the hands of the contractor, but £12 has been paid for renewal of tools, and also cremator bars. The area of land enclosed by building wall is 5200 square yards, part of which is to be utilised for stable buildings. Gas coke is used in the cremator, costing 6s. per day. No complaint of nuisance has arisen in the neighbourhood from the working of the Destructor. The surplus heat is not utilised. Builders cart away the clinker and ashes free of charge.

Waterloo-with-Seaforth.

The area of the district is 1524 acres, the population 21,900, and the rateable value £97,200. The question of the disposal of the house refuse is under consideration, and will probably be settled during 1898.

Warrington.

The area of the district is 3115 acres, the population 62,000, and the rateable value £199,600. There are four Destructor cells of the Beaman and Deas type. The old Destructor consisted of 6 cells of the "Fryer" type, but is not now in regular use. The Corporation also carries on the manufacture of concentrated manure, the motive power being derived from the Beaman and Deas cells. The material burnt consists of unscreened town's refuse, of which the regular consumption is at the rate of 15 tons per cell per twenty-four hours; but the furnaces are capable of dealing with about 24 tons each per day. The cost in labour of destroying the refuse is 9½d. per ton.

About 1·5 lb. of water are evaporated per pound of refuse, and boilers of 298 total horse-power are installed for the utilisation of the heat from the cells. The boilers are placed above and between each pair of furnaces, so that the full calorific value of the refuse is utilised. It is proposed to combine the destruction of the town's refuse with the electric lighting scheme, the Provisional Order for which is now before the Board of Trade.

The Beaman and Deas cells are built in pairs, charged from the top, and clinkered at the side instead of the front, as in other types. The sloping drying hearth is situate in the front of the cell, next is the grate, and beyond are the combustion chambers, short flues, and a Babcock and Wilcox boiler, so that the fumes from the material on the drying hearth pass over the hot fire on their way to the flue.

The grate area is about 25ft., and the fire-bars are fixed, being preferred to loose or rocking bars; they are in two rows, each 2½ft. long, 8in. in depth at the centre, ⅞in. wide at the upper, and ¼in. wide at the lower surface, the air space being $\frac{3}{16}$in. wide between the bars, so that none but the finest ash can pass through the grate.

The air blast, produced by means of a fan, 3ft. diameter, turning 1200 revolutions per minute, is introduced underneath the fire-bars in the ash chamber, which is closed by iron folding doors, and can be regulated by handles at the side of the furnace.

When the clinkers are being lifted for drawing out, it is seen that the bottom surface next to the fire-bars is quite black, showing that the bars are practically cool through the action of the drying hearth. When the charge is properly laid and the furnace closed, the blast is then turned on. It occupies about half-an-hour to destroy each charge from the time of turning on the blast to commencing drawing the clinkers, or, on the whole, about three-quarters of an hour in charging, burning, and clinkering ready for the next charge. During the time one charge is being destroyed the men are engaged clinkering and re-charging the adjoining cell, and so they continue throughout the day. The men, six in number, work in two shifts of twelve hours each, and are paid at the rate of 26s. per week.

By the action of the blast, small particles of dust and cinders are blown up to the arch in a form of spray, and such particles adhere to the underside of the arch, gradually accumulating in the form of stalactites, which can be plainly seen through the open furnace doors, thus protecting the brickwork from the action of the continued intense heat. The chimney shaft is 120ft. high, 4ft. inside diameter at the bottom, and 3ft. 6in. diameter at the top. When erected it was not designed to do the work it is now doing, and is considered too small.

These works include, in addition to other cells before mentioned buildings partly under the same roof, which are fitted up with engines, machinery, and plant for drying and manufacturing the whole of the excreta from the pail closets in the borough. The excreta is sent from the depôt in the town, over a mile away, through pipes by Shone's ejectors, and caught in receivers, and undergoes a process of converting into a powder manure, after which it is filled into bags, and sold to the farmers in the country districts. The manure factory contains thirteen engines, water-pumping engine, repairing shop, and vacuum fans to evaporate the moisture from the excreta—a total of about 200 to 230-horse power.

West Hartlepool.

The area of the district is 2470 acres, the population 55,000, and the rateable value £195,000. The Corporation is now considering the subject of refuse disposal by burning, and a deputation has recently visited various installations. It is intended to select a Destructor which will be thoroughly efficient as regards the satisfactory destruction of the refuse, and at the same time enable the maximum amount of heat to be got for the purpose of the town electric lighting station.

The quantity of refuse in West Hartlepool to be removed yearly, estimated on a population of 44,000, is about 14,000 loads, which is equal to ·32 load per person, or 320 loads per 1000 inhabitants per annum.

In 1892 the Borough Engineer, Mr. J. W. Brown, A.M.I.C.E., prepared the following "estimates of dealing wholly and completely with the quantity of refuse then made and collected":—

Estimated Annual Cost of Cleansing Ashpits by the Corporation Staff.

			£	s.	d.
11 horses and carts, and men,	per week,	45s.	1287	0	0
6 men throwing out refuse,	,,	24s.	374	8	0
4 men sweeping,	,,	20s.	208	0	0
4 men filling,	,,	21s.	218	8	0
2 men in charge of depôts,	,,	20s.	104	0	0
1 superintendent,	,,	40s.	104	0	0
1 salesman,	,,	30s.	78	0	0
Lights, brushes, shovels, repairs, &c.			50	0	0
Depreciation of carts, horses, &c., £990 at 10 per cent. ...			90	0	0
Repayment of loan, principal, and interest, for stables, cartsheds, land, &c., at 30 years, £1500, at 3½ per cent.			78	0	0
			2600	16	0
Less sales of manures, 7000 loads, 1s.			350	0	0
			2250	16	0

Annual Cost of Cleansing Ashpits by Contract.

	£	s.	d.
Amount of contract, District No. 1	1000	0	0
" " " No. 2	700	0	0
" " Seaton Carew	30	0	0
1 superintendent at 30s. per week	78	0	0
Balance (adverse)	442	16	0
	2250	16	0

Sea Disposal.

	£	s.	d.
12 horses, carts, and men, per week, 45s.	1404	0	0
6 men throwing out refuse, " 24s.	374	8	0
4 men sweeping, " 20s.	208	0	0
4 men filling carts, " 21s.	218	8	0
2 men in charge of depôt " 20s.	104	0	0
1 superintendent, " 40s.	104	0	0
Lights, brushes, shovels, repairs, &c.	50	0	0
Depreciation of horses, carts, &c., 12 in number, £1080, at 10 per cent.	108	0	0
Repayment of loan, principal, and interest, on stables, cart-sheds, works at depôt, &c., at 30 years, £1500, at 3½ per cent.	78	0	0
Depreciation on two barges, £600, at 5 per cent.	30	0	0
14,000 loads refuse towed out to sea, 6d....	350	0	0
Wharfage, &c...	50	0	0
	3078	16	0

Disposal by Destructor.

	£	s.	d.
9 horses, carts, and men, per week, 45s.	1053	0	0
6 men throwing out refuse, " 24s.	374	8	0
4 men sweeping, " 20s.	208	0	0
4 men filling carts, " 21s.	218	8	0
1 superintendent, " 40s.	104	0	0
Lights, brushes, shovels, repairs, &c.	50	0	0
Depreciation of horses, carts, &c., 9 in number, £1053, at 10 per cent.	105	6	0
Repayment of loan, principal, and interest, on stable and cartsheds, at 30 years, £1000, at 3½ per cent.	52	13	4
Repayment of cost of Destructor and site, at 30 years, £6500, at 3½ per cent.	342	6	8
14,000 loads refuse burnt, 1s. 3d.	875	0	0
	3383	2	0

It will be observed that the estimated cost of removing and disposing of the town refuse by the Corporation staff is in excess of the tenders sent in by £442 16s. This is largely caused by the fact that a contractor has greater facilities for disposing of the material than the Corporation would have, since he has a large farm upon which thousands of tons have been, and are being, spread. The cost of the sea disposal is £1270 16s. in excess of the present system. This sum could be materially reduced if wharfage could be obtained within the dock gates; the distance to Middleton is excessive. The estimated cost of total disposal by a Destructor is in excess of sea disposal by £304 6s., and £1575 2s. in excess of present system. This is caused by the cost of land for depôt, buildings, machinery, and no receipts for manure. The Borough Surveyor reported, "from a sanitary point of view there is no comparison; the disposal by fire is immeasurably superior to any other known method."

Westminster.

The area of the district is 813 acres, the population 53,234, and the rateable value £875,688. In Westminster (St. Margaret and St. John) there is a Cornish boiler, 26ft. long, with a grate area of 22 square feet, set upon Livet's principle. This furnace deals with house refuse only, and sufficient steam is raised to work a 40-horse power engine, but a 12-horse power only is used. This engine runs a dynamo and various machinery connected with different workshops. The shaft is 60ft. in height, and no appreciable smoke arises therefrom.

Whitechapel.

The area of the district is 357 acres, the population 77,800, and the rateable value £435,400. The Destructor consists of sixteen cells of the Fryer type, the first of which were erected in 1886. This Destructor is situated in the midst of what is probably the most densely populated area in the world, and deals with house and trade refuse at the rate of about seven tons per cell per twenty-four hours, without giving rise to nuisance to the neighbourhood. The cost for labour in burning is 1s. 1d. Work is continuous from 6 a.m. Monday to 6 a.m. Sunday, each day being divided into three eight-hour shifts. The two day-shifts consist of—Two furnacemen at 6s. per day, two wheelers at 4s. 6d., and three chargers at 4s. 6d. The night shift has only two chargers. There is also a foreman in charge, whose wages amount to 42s. per week. The temperature in the flue averages 1350 deg. Fah.; but there are no boilers, and the heat is not utilised. The chimney is 180ft. in height. The cost of the works, exclusive of site, was £10,500.

Winchester.

The area of the district is 1043 acres, the population 19,100, and the rateable value £92,500. The Destroyer consists of 2 cells, one by Messrs. Manlove, Alliott, and Fryer, erected in 1884, and the other by Messrs. Goddard, Massey, and Warner, erected in 1891. The material dealt with consists of ordinary house refuse, including offal from fish shops, fruiterers, &c. Meldrum steam blowers have recently been added to the furnaces, and, in the opinion of the superintendent, the cells "now do about double the work and make a better clinker." The furnace-bars are kept in a better state by the moisture of the steam, and therefore last longer, but the brick lining suffers from the greater heat. There is a better combustion, and therefore greater efficiency in the disposal of the refuse. The labour of burning costs about 10d. per ton.

Eighty to 100 tons a week are burned; the large tins and iron pans are sorted out and buried, but the small tins are put through the furnace, and the solder melted out into the clinker.

The furnaces are worked every day and night, except that the men are only in attendance six hours each Sunday; for the rest of the week two men are at work by day and one by night.

The works are on the outskirts of the city, but there are many good houses close by, and a building estate is being laid out adjoining the site of the works, and we were assured there were no complaints, except a few as to smoke before the blowers were put in.

The Destructor has been erected at the sewage outfall, and the waste heat is used for assisting in raising steam for pumping the sewage to the farm, which is situated about three-quarters of a mile away; this is effected by means of a Green's economiser fixed in the hot-air flue, which saves about 30 per cent. of the coal bill as compared with former costs.

There is a good demand for the ashes at 1s. 6d. per load, and for the clinker at 2s. per load; what is not sold is made up by hand into paving stones. The clinker here is of very hard quality.

The flue from the Destructor is connected with the main flue of the shaft at the sewage pumping station, which is 80ft. in height.

The cost of the works, exclusive of shaft and site, was £660.

Withington.

The area of the district is 5728 acres, the population 31,500, and the rateable value £196,700. The Destructor consists of six cells of the Town Surveyor's design, and has been in successful operation since October, 1895. The material dealt with is dry and midden ash-pit refuse, which is burnt at the rate of from seven to eight tons per cell per day, and the cost for labour is 8d. per ton.

There is a 30-horse power boiler, 11ft. by 7ft., with 83 4in. tubes, which generates steam for working a mortar mill, dynamo, and donkey pump. It will also be used for working hydraulic pumps of concrete flag-making machinery which is about to be fixed.

The shaft is 150ft. high above ground, and 170ft. from main flue to the top.

The cost of the works, including the formation of an approach roadway 460 yards in length, was £6600.

Woolwich.

The area of the district is 1126 acres, the population 41,400, and the rateable value £271,400. The Destructor consists of six cells of the "Fryer" type, erected in 1893. The material burnt is house and trade refuse, including fishmongers' and butchers' offal. The surplus heat from the furnaces is not utilised.

The chimney shaft is 160ft. high, and the cost of the works about £5000.

The following is the Surveyor's report upon the cost of disposal of Refuse at the Destructor, Dockyard Wharf, for the period of one year ended December 3rd, 1896 :—

The quantity of refuse that passed through the cells during that period amounted to 11,387 loads, being an increase of 569 loads on the previous year.

The cost of the disposal of which, under the old system of barging away at 1s. 6d. per cubic yard, would have been (calculating each load to represent two cubic yards) £1,708 1s. 0d.

564 tons of fishmongers' and butchers' offal were also destroyed during the year, being an increase of 79 tons upon the quantity destroyed last year.

The outgoings of the Destructor, including capital and interest on loans, wages, breeze for cremator, gas, water, and other expenses, were as follows :—

		£ s. d.	£ s. d.
Capital and interest on loans for erection of Destructor			468 15 10
Wages gross		638 13 9	
	£ s. d.		
Cr. Man's time attending Disinfector	55 4 1		
Value of the clinkers, &c., used on the roads by the Local Board, estimated at 6d. per load	21 5 0		
By sale of clinkers, &c., 1233 loads at 6d. per load	30 16 6		
		107 5 7	
			531 8 2
Carting clinkers to shoot 1347 loads at 1s. 3d.			84 3 9
Carting away old tins, 150 loads at 2s.			15 0 0
Breeze for cremator, 309 cubic yards at 2s. 9d.			42 9 9
Gas			37 9 0
Water			5 0 0
Repairs to barrows, tools, &c., smith's work			14 0 11
Repairs to cells and Destructor generally			48 19 8
Clogs for Stokers			4 7 0
Income tax			7 4 5
Parish rates			56 4 6
			£1,315 3 0

	£	s.	d.
The removal by barges would have cost	1,708	1	0
The disposal of the same quantity by Destructor cost	1,315	3	0
Showing a saving of	392	18	0

The Destructor was erected on land belonging to the Board, and the value of such land is not included in the above statement.

The saving this year is less than last year in consequence of the increased amount paid for rates and taxes and for carting away residuum, for which there was no sale. But for these items the saving would have been £505 1s. 9d.

York.

The area of the district is 3692 acres, the population 72,083, and the rateable value £255,085. A 6-cell Refuse Destructor was erected here in 1895 by Messrs. Goddard, Massey, and Warner.

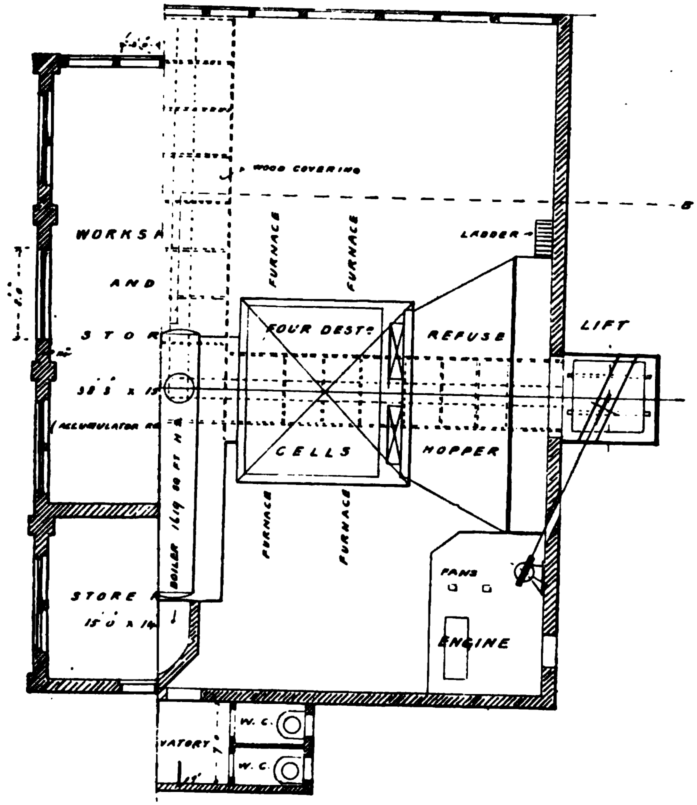
Since going to press the following particulars of a combined Destructor and electricity undertaking now being installed at Canterbury have come to hand:—

Canterbury.

The area of the district is 3955 acres, the population 23,026, and the rateable value £109,950. Hitherto the refuse has been sent to "tips" on land or sold as manure.

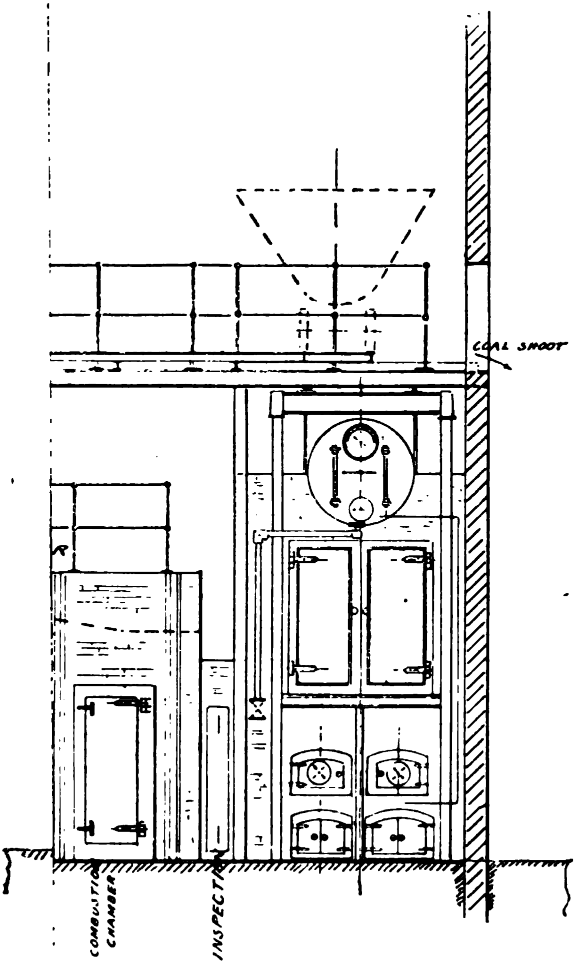
The Corporation are at the present time laying down works for the utilisation of the heat from Refuse Destructors in course of erection for the production of electricity. As far back as 1892 a Provisional Order was obtained from the Board of Trade enabling the Council to supply electric light and power within the city. This Order had remained in abeyance until recently; but, under the advice of their Engineer and Surveyor, they decided upon the combination of Refuse Destructors with Municipal Electricity Works. Contracts have been entered into between the Corporation and Messrs. Beaman and Deas, Refuse Destructor manufacturers, for the provision of adequate plant to consume the refuse of the city.

It is anticipated that enough steam will be obtained from the Destructors to provide for the wants of the Destructor itself during the day, and to drive the electric dynamos for the night load. Under the contract, the plant, which consists of one pair of cells, is required to be capable of effectually cremating 5000 loads of refuse per annum of 300 working days. The hours of



ENERAL ARRANGEMENT.

tructor Cells."



Fi ILDING ALONG LINE A B ON PLAN, SHOWING
BY LIFT.

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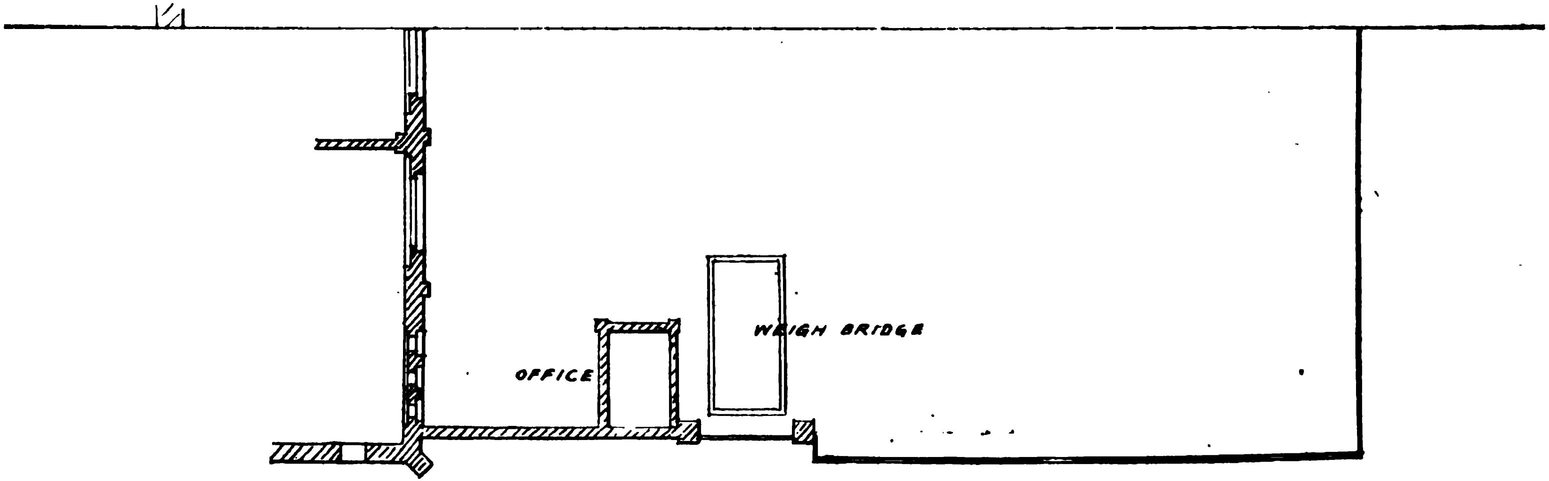

Fig. 70—BERLIN DESTRUCTOR WORKS—BLOCK PLAN, SHOWING GENERAL ARRANGEMENT.

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daily working are to be between 10 a.m. and 10 p.m., and within these twelve hours the plant must be capable of cremating eighteen loads, of an average weight of 17 cwt. each, *i e.*, at the rate of over 15 tons per cell per twenty-four hours. The furnaces are to be worked by forced draught, provided by a fan, and in order to prevent any bad odours and dust escaping into the Electric Light Works and the surroundings, the air for the draught will be drawn through an air channel immediately over the refuse hopper. Any foul air therefore arising from the refuse will be passed through the furnaces to the chimney shaft. As the site will not readily admit of an inclined roadway and platform, a hoist has been provided with a large refuse tank and shoot over the furnaces. The refuse as discharged from the carts is shot into the lift stationed in a pit 6ft. deep, and from thence is elevated into the feeding bins or hoppers by the hydraulic or belt-driven lift. This lift will also serve for raising the coal to the coa bins.

The buildings have been planned so as to keep the actual dust-shed well separated from the electric plant. The steam from the Destructors will be stored in a Babcock and Willcox boiler of about 1700 square feet of heating surface; and the draught of steam required for the electric plant will be about 2250 lb. per hour, which, it is estimated, the Destructor plant will yield. The Destructor building is absolutely self-contained, and, with a view of avoiding offence from the escape of dust into the immediate neighbourhood, which is thickly populated, no ventilation of the building has been permitted to the open air. The cost of the Destructor buildings, chimney, and land is about £4000, and, including the Electricity buildings, £7500.

These works, which are illustrated in Figs. 68 and 69, prepared from drawings kindly lent by the City Surveyor, will be ready for working in November (1898), and the results of the combination of Electricity Works on a fairly large scale, with Refuse Destructors, will doubtless be watched with considerable interest.

Berlin.[1]

In 1893 the Municipal Authorities of Berlin turned their attention to the question of refuse destruction by fire; and inquiries into the systems of cremation in vogue in many English towns having been made, the Municipal Council, at a meeting held on the 16th June, decided to devote the sum of 100,000 marks to experiments in this direction. In April, 1894, Messrs. Bohm and Grohn (Town Councillor and Government Architect) published a report upon English systems of refuse destruction, subsequent upon a visit of inspection to this country. As a result of this report, it was decided to establish two systems for experimental purposes—the Warner and Horsfall Destructors respectively.

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[1] "Report on Refuse Destruction in Berlin," by Messrs. Bohn and Grohn.

Messrs. Goddard, Massey, and Warner, of Nottingham, supplied three cells, and the Horsfall Refuse Furnace Company (now the Horsfall Furnace Syndicate, Limited), of Leeds, supplied two cells at first and subsequently a third cell. These Destructors were erected in 1895. In January, 1896, a further sum of 30,000 marks was granted for the purpose of continuing the experiments, and the entire sum, with the exception of a few thousand marks, has been exhausted.

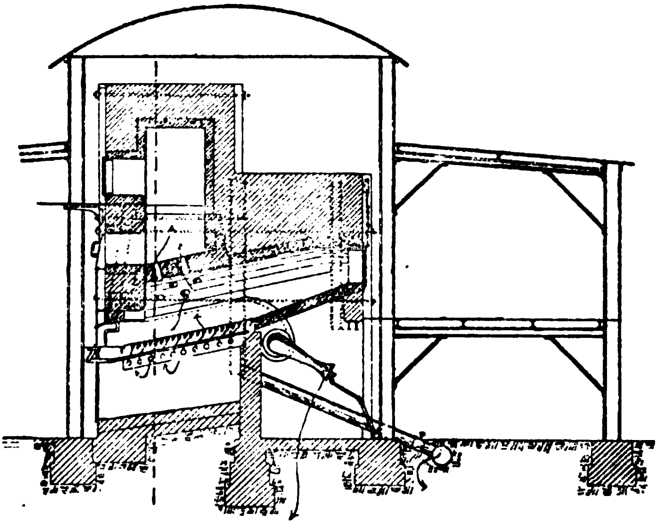

Fig. 71—Berlin Destructor Works—Cross-section of the Horsfall Cells.

Cost of Erection.—The exact cost of the experimental installation is not stated; but it has been calculated that the cost of erection of a single cell, including sheds, machinery, chimney, &c., would amount to 12,500 marks. The census of 1895 placed the population of Berlin at 1,677,135, and it is estimated that to consume the entire refuse of the town six Destructors, with 42 cells each, would be required.

Class of Refuse Burnt.—The refuse consumed in the Destructors consisted of bits of coal and coke, paper, rags, bones, wood, plant and animal refuse, cinders, glass, iron and various other metals, and crockery. The proportions vary considerably in the different quarters of the town. The combustibleness of the refuse is affected by the seasons. Contrary to experience in England and in Hamburg, it has been found that the Berlin refuse is less combustible in winter than in summer. This is attributed to the fact that in Berlin bituminous coal is used almost exclusively, while in this country and in Hamburg anthracite coal is used, the residuals from the hard coal being far more combustible than those from bituminous coal; the latter are found to retard rather than to aid the combustion of refuse.

Capacity of Each Type of Furnace.—Each cell of the "Warner" furnace was found capable of consuming, on an average, 4740 kilos. of unsifted or 8216 kilos. of sifted refuse in twenty-four hours, fan draught being used. Each cell of the "Horsfall" furnace was found capable of consuming, on an average, 5383 kilos. of unsifted and 10,105 kilos. of sifted refuse with the use of fan draught, and 8202 kilos. of unsifted and 6149 kilos. of sifted refuse with the use of steam-jet draught. In the case of the Warner Destructor, 0·49 per cent. of coal was added to aid the combustion of the unsifted refuse. With the sifted refuse no combustible was necessary. In the case of the Horsfall Destructor, 0·50 per cent. of coal was added to the unsifted refuse with the use of fan draught, and 1·71 per cent. to the unsifted and 0·08 per cent. to the sifted refuse with the use of steam draught.

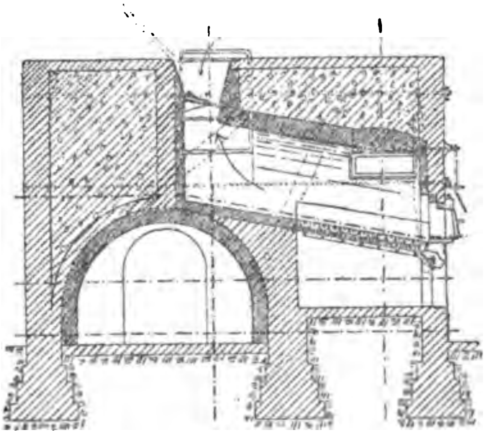

Fig. 72—Berlin Destructor Works—Cross-section of the Warner Cells.

Steam Power Obtained from Refuse.—Repeated experiments have shown that the heat generated by the combustion of the refuse in

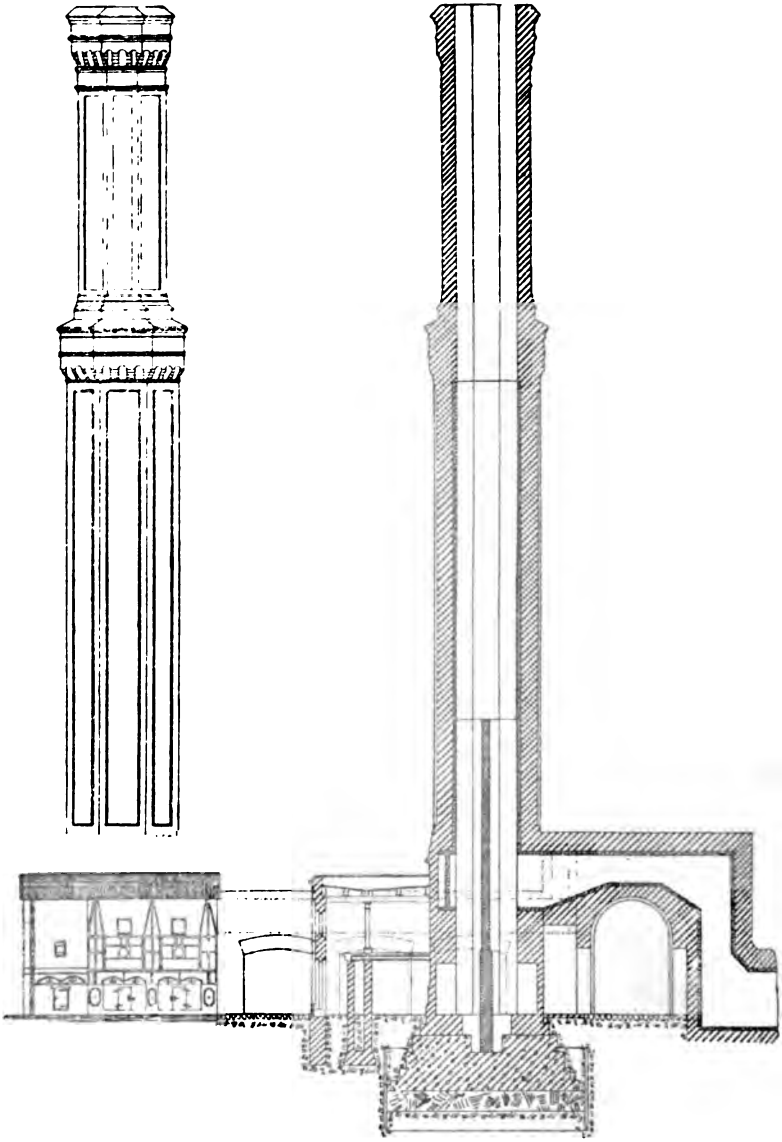

Fig. 73 - Berlin Destructor Works—Section along Line A B.

either type of furnace is not sufficient for the production of steam. The temperatures obtained varied from 120 to 150 deg. Cent. during the early periods of trial, and rose to an average of 288 deg. (variations of 50 to 600 deg) during a period of observation extending from the 11th to the 21st of September, 1895. The steam required for the working of the Destructors was generated in a specially-constructed boiler. A permanent system of Destructors would require a special steam boiler installation, which would involve an expenditure of combustibles which does not exist in the English installations or in Hamburg, where sufficient steam is generated by the heat from the gaseous products of combustion. The difference between the generation of heat in English and Berlin refuse cremation is attributed to the fact that Berlin refuse contains about 1·82 per cent. of half-burnt coal, while English refuse contains about 28·8 per cent. More favourable results are obtained with sifted refuse. With the use of steam draught the pyrometers showed a variation in temperature from 130 to 630 deg., the average being 401 deg. In view of the fact that in the case of a larger number of cells the variations would not be so great, and that the use of fan draught results in an increase in temperature, it is to be presumed that the combustion of refuse that has been freed from ashes would result in the generation of sufficient heat for the heating of steam boilers.

Residuals.—The residuals consist of 36 per cent. of clinkers and 14 per cent. of ashes by weight, and of 27 per cent. of clinkers and 10 per cent. of ashes by bulk. Assuming that these residues cannot be applied to any use, their storage would require 87 per cent. less room than is required for the accommodation of the refuse under existing arrangements. There are, moreover, no hygienic objections to their storage near the town; and this fact, coupled with the decrease of 50 per cent. in weight, would make their transportation considerably cheaper than the carriage of the refuse under existing arrangements. Various attempts have been made to find a market for the residuals, but up to the present these have not met with much success. The residues are considered useful for the levelling of ground and the mending of roads, and a small quantity has been used by private persons for this purpose; but no profit was made out of the transaction, since the users required payment for carting the stuff away! Experiments show that the clinkers might be of value for the making of foundations for asphalt roads, &c., but no business has been done in this direction. An attempt was made to use pounded clinkers in place of sand for asphalt paving, but the result was unfavourable. It was found that in wet weather the clinkers increased the slipperiness of the pavement to a dangerous degree. Berlin annually produces about 239,100 tons of refuse, which if cremated would yield about 119,550 tons, or 148,000 cubic metres, of residuals. It has been calculated that if the clinkers could be used to advantage in the making of asphalt roadways, about 10,000 cubic metres could be disposed of in this way. No attempts have been made to use the residues for agricultural purposes, for the analyses made did not hold out any hopes of favourable results in this direction.

Miscellaneous Notes.—The disused waterworks of the town is the site of the trial Destructors. As the Destructors were not intended as a permanent installation, various economies were practised in order to reduce the expense of their erection:—

(1) The chimney of the waterworks (39 metres high and 2·44 metres diameter) was found to answer the purpose excellently.
(2) No inclined roadways were built, the refuse being raised to the mouth of the cells by a hand crane.
(3) A special shed was considered unnecessary for the furnaces, which were protected from the weather by roofs of corrugated zinc.

The two systems were kept entirely distinct, each having its own flue, terminating on opposite sides of the chimney. The installations have been so arranged that they may be enlarged, if necessary, by the addition of further cells. An analysis of the gaseous products of combustion revealed the presence of carbonic oxide—a fact which showed that combustion was imperfect. In dull, wet weather the gases escaping from the chimney fell to the ground instead of rising perpendicularly, and on these occasions a slightly disagreeable smell was sometimes perceptible. This smell was due to the insufficient combustion of the gases. The health of those employed at the furnaces was reported good. For the earlier experiments with the Destructors German workmen were employed. The unfavourable results obtained led to the employment of English workmen in the case of the Horsfall Destructor, but the results obtained by these did not justify the experiment. The comparative failure of the experiments is ascribed to the inferiority of Berlin refuse.

The general arrangement of the Berlin works are illustrated in Fig. 70, and the details of the cells in Figs. 71, 72, 73.

CHAPTER XI.

THERMAL STORAGE.

In practical engineering there are numerous instances in which some means of storing energy in such a way as to readily admit of being transformed into mechanical energy is eminently desirable.

In practice this storage is provided for daily use in various ways, such as by the coiling of elastic metal springs and raising masses of metal, as in clocks and watches; by the use of fly-wheels; by dissociating chemical compounds, as in the case of storage cells, &c.; by compressing air and storing in cylinders; and by pumping water up to a high-level reservoir, thereby gradually accumulating a store of mechanical energy which may be expended according to the demand.

There is another means of providing this store, viz., that of *heat* or *thermal storage;* and this, in view of the importance of its bearing upon the utilisation of the surplus heat from Refuse Destructors, will here be further considered.

A system of thermal storage has been devised by Mr. Druitt Halpin, M. Inst. C.E., the first public mention of which was made by Professor Unwin in the course of his Howard Lectures at the Society of Arts, in January, 1893. The invention consists in the storage of the continuous thermal work of one or a small number of boilers working continuously at their best load to do the work of several or a large number of boilers for short periods of maximum load.

The principle upon which the invention is based is old, and has been understood since the discovery by Black in 1762 of the latent heat of generation of steam and its difference under different pressures of evaporation. The principle is also illustrated in the philosophical toy (the Cryophorus) invented by Dr. Wollaston, in which, as soon as the vapour pressure is removed rapid evaporation commences.

The temperature of boiling point increases with the pressure, and, a liquid boils when the tension of its vapour is equal to the pressure it supports. The relation between any given temperature of water and the pressure of the steam it supports is given by Regnault in his table of the properties of saturated steam. Supposing high temperature water contained in a hermetically-sealed vessel to be drawn off into a second vessel where the pressure is less than the pressure corresponding to the temperature of water in the first vessel, the water so drawn off will immediately boil and develope steam rapidly until a pressure has been established in the second vessel corresponding to the temperature, and so assuming a condition of equilibrium. In the ordinary steam boiler, as soon as steam is withdrawn by the engine the pressure is relieved, and water is instantly evaporated into the steam space to keep up the pressure.

Heat to be accumulated must, of course, be communicated to some material body, and nothing could answer this purpose better than storage by raising water under pressure to a high temperature. Immediately upon reducing this pressure steam is generated and in an absolutely determinable amount.

Mr. Halpin in his system, which meets the fluctuations in the demand for steam energy at power-using stations, employs boilers equal to the *mean* demand for steam and cylindrical storage tanks containing water under pressure which is heated up by the circulation of water or steam to a temperature above the saturation temperature of the steam used in the engines.

The storage reservoirs, in size 30ft. by 8ft., are provided sufficient in number to give a capacity of about 16 lb. of heated water per pound of steam required during the period of demand which is above the mean load. The boilers and storage reservoirs are of course in communication, and there is a free circulation of heated water between them.

Steam is generated in the constantly-working boilers at a pressure of 250 lb. per square inch (265 lb. absolute), this being also the pressure in the reservoir. From the top of these reservoirs steam is taken off through a reducing valve for the supply of the engines, which are worked at a pressure of 115 lb. per square inch (130 lb. absolute). Any reduction of pressure at the reducing valve causes steam to be given off by the mass of heated water at a rate depending upon the difference of total heat at its initial temperature and the temperature of steam used in the engines.

The boilers are fed by an ordinary feed pump, which supplies water direct to them to make up for the waste in generating steam, thus keeping the water level in the storage tanks at a constant height. In the boiler the water is constantly being heated and then passed into the storage tanks, where the steam is given off as required—the water consequently falling in temperature. The cooled water, together with the feed, is then circulated back to the boiler. Where there is a battery of such storage tanks the steam spaces would all be in communication with each other, so that the pressure will be uniform throughout.

In the practical installation of the system the precautions which appear necessary are :—To provide against radiation of heat; to ensure a sufficiently complete and rapid circulation into the storage reservoirs; and, where there are several of these tanks in use, to ensure that when the pressure is reduced at the top of the tanks the steam is then given off just where wanted, and not where it would embarrass.

Looking at the subject quantitatively, from a thermodynamic point of view, as above mentioned, Mr. Halpin generates steam in the boilers at a pressure of 265 lb. per square inch absolute, and works the engines at 130 lb. pressure absolute. The temperatures corresponding to these pressures are 406 deg. and 347 deg. respectively, so that in the reservoirs, when the water is called upon to give up its stored heat in the form of steam, evaporation proceeds until the temperature has fallen from 406 deg. to 347 deg., *i.e.*, a range of temperature of $406 - 347 = 59$ deg.

The heat required to raise 1 lb. of water from 347 deg. to 406 deg. is 61·37 units, so that it may be assumed that each pound of water in the reservoir will, in falling through 59 deg., give off at least 60 units of heat.

The total heat of steam at 130 lb. pressure, or, in other words, the heat required to evaporate 1 lb. of water at 347 deg. is 868·8 units, so that it will require $\frac{868 \cdot 8}{60} = 14 \cdot 48$ lb. of the pressure water at 406 deg. to develope 1 lb. of steam at 130 lb. pressure, or 347 deg. temperature; or, leaving a margin for losses, it may be taken that 16 lb. of water will be required to generate 1 lb. of steam.

Assuming the storage reservoir to be 30ft. by 8ft. diameter, it will contain about 1850 cubic feet, or about 85,000 lb. of water, allowing space to give evaporation surface. Each of such reservoirs, therefore, would give off $\frac{85{,}000}{16} = 5300$ lb. of steam at a pressure of 130 lb. per square inch.

Assuming 20 lb. per electrical horse-power as the rate of consumption of steam per hour by condensing engines, and 27 lb. by non-condensing engines, a storage reservoir as above described, then, gives $\frac{5300}{20} = 265$ effective horse-power hours, or $\frac{265 \times 746}{1000} =$ 197 kilowatt hours, for condensing engines, and $\frac{5300}{27} = 196$ effective horse-power hours, or $\frac{196 \times 746}{1000} = 146$ kilowatt hours, for non-condensing engines.

Heat storage is applicable to all steam-using works, and such a system will be especially advantageous where the demand for power fluctuates largely, as is the case at electric light stations where the storage of energy would greatly facilitate and economise the work to be done. The economical production and distribution of electricity for electric lighting and electric transmission of power has been embarrassed by the want of an efficient means of electrical storage. The demand for current is extremely irregular during the twenty-four hours, the *maximum* demand being about four times the *mean* demand. The period during which the demand exceeds the mean is comparatively short, and does not exceed seven or eight hours out of the twenty-four, whilst for a portion of the time the demand may not exceed one-twentieth of the maximum demand.

It has been shown that, with machinery used in a London electric light station, the station can be worked when running at full load with a fuel expenditure of 4·5 lb. of coal per hour per kilowatt of current delivered, whilst the actual consumption with an irregular demand for current is 9 lb. of coal per kilowatt delivered. Experience thus shows that this waste doubles the cost of fuel per Board of Trade unit of current. In the absence of storage, the waste is unavoidable, as neither boilers nor engines work continuously under the best and most economical conditions, *i.e*, at nearly their full load.

The difficulty with regard to engines is largely overcome in full-sized stations with a number of engines, as those in use can be always working at the economical load, but this does not apply to the case of boilers. These cannot be made to consume fuel in proportion to the steam to be produced, owing to the necessity of working them at full load for short periods only. Fuel is used in getting up steam, in keeping boilers under steam to meet the periods of maximum demand, which, ceasing rapidly, as it usually does, leaves all the furnaces with fire sufficient to continue the production of steam which is then not required. It is to the saving of this waste that Mr. Halpin's system is directed.

There are various plans upon which an electric light station can be arranged :—

(*a*) Boilers, engines, and dynamos, sufficient to meet the maximum demand may be installed to be used or not, according to requirements.

(*b*) Boilers, engines, &c., sufficient to meet the maximum demand, but the whole plant to be shut down when the demand is very small, and the current then supplied from electrical storage batteries.

(*c*) Boilers, engines, &c., of less strength than in case (*a*), but combined with large storage batteries capable of discharging a large proportion of the whole current during maximum demand.

(*d*) Boilers adequate for *mean* demand only, but engines and dynamos sufficient to meet the maximum demand. The boilers would work continuously at nearly full power, and all surplus heat be stored in thermal storage reservoirs for use when required.

The first system (*a*) is a usual arrangement, and necessitates laying down a large boiler plant which, owing to the variations in the demand for current, must be kept in steam ready for use at a moment's notice. The electrical accumulator or storage batteries in case (*b*) would be capable of supplying only a small part of the total demand, probably about one-fifth of the mean. Some economy may be derived from this mode of working, but electricians are not unanimous upon this point. As regards the third method of working, using engines and boilers sufficient for the mean demand only, the cost of the electrical storage batteries which would be required would be so great as to reduce such a scheme to a financial failure. The electrical storage would require to be capable of discharging during short periods of maximum demand nearly three-fourths of the whole current.

Therefore, as the storage of electricity to an extent sufficient to admit of the use of boilers adequate for the mean demand only is financially impossible, Mr. Halpin has devised his system with a view of overcoming the difficulty by means of the storage of that which produces the electricity, viz., *heat*.

As regards the financial side of the question of thermal storage, a reservoir as above mentioned, erected with appendages and making allowance for the necessary building, costs about £470; consequently, according to Professor Unwin, the cost of thermal storage reckoned on the energy stored would be £1·64 per electrical horse-power hour for a condensing plant and £2·24 per electrical horse-power hour for a non-condensing plant, as compared with £8 per electrical horse-power hour for battery storage. Besides this, the electrical loss in the storage batteries amounts to 20 per cent., and the cost of upkeep of the batteries is generally reckoned at 12 per cent—a much higher cost than need be estimated for the upkeep of the thermal reservoirs.

Whilst Mr. Halpin's system of thermal storage is applicable to all power-using stations, it should be found of special advantage at places where there is heat which is now wasted. This is very generally the case with Town Refuse Destructor installations. The Destructor is worked day and night at practically a uniform rate, and the heat produced requires to be caught at the moment generated or is lost altogether.

Another important instance of the waste of heat, and to which Mr. Halpin has suggested the application of thermal storage, is to be found in the enormous industry of gas manufacture. There are in the United Kingdom some eleven millions of tons of coal carbonised annually for gas making, and Professor Unwin has estimated that the available part of the waste heat in the retort banks—at present usually all wasted—amounted to not less than 82,000 effective horse-power day and night throughout the year.

This system of thermal storage, with some modifications, has been installed at the Shoreditch Destructor and Electricity Station, for particulars of which see pages 327 and 328.

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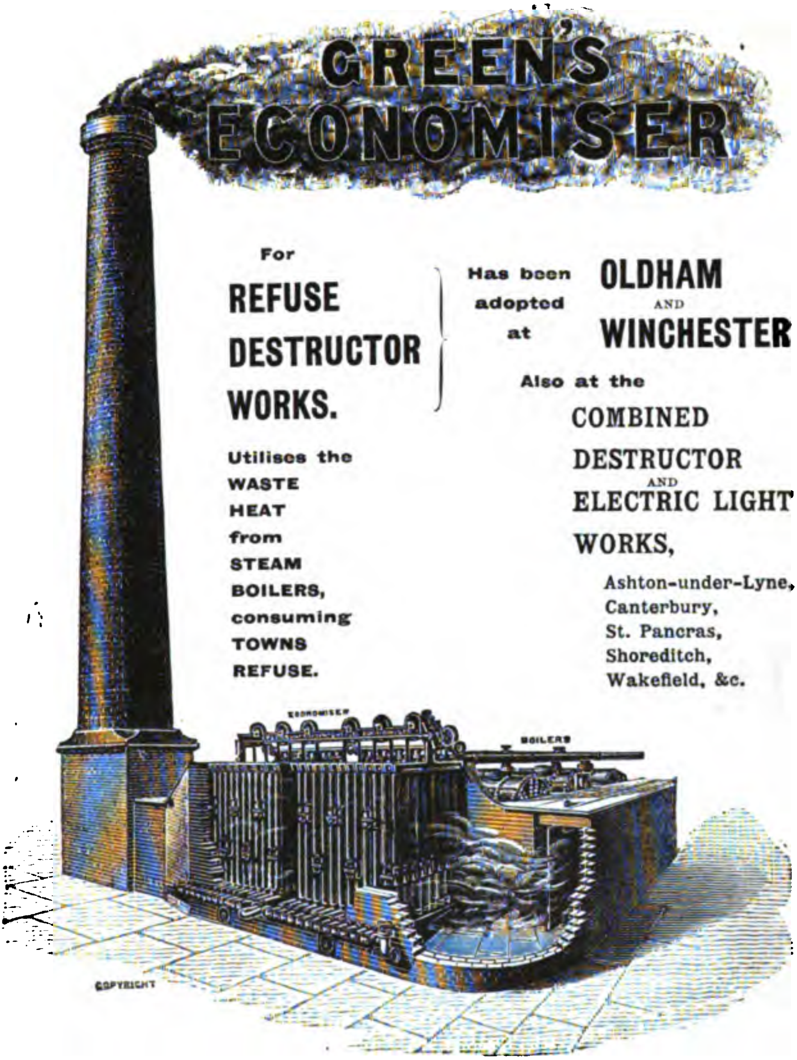

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